Ecological water requirements for selected wetlands in the Murray drainage and water management plan area

Murray Drainage and Water Management Plan and Associated Studies

This report was prepared for the Department of Water

September 2010

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Executive Summary

Background

This study, *Ecological water requirements for selected wetlands in the Murray drainage and water management plan area*, forms part of a wider multidisciplinary study undertaken to inform regional urban water management in the Murray DWMP study area.

The Murray region has been identified by the Western Australian Planning Commission and local government authorities as a high priority for structure planning, which will provide guidance for future development and management of environmental issues.

The DWMP will provide guidance on how water quantity and quality can be managed to minimise any adverse impacts on the environment and how to ensure sustainable development. As part of the planning process, a scientific understanding of surface and groundwater regimes and the ecological water requirements (EWRs) of selected wetlands is critical for identifying potential impacts on the natural environment.

Study approach

This study provides interim regional-scale EWRs, along with monitoring and contingency plans, for selected Murray wetland sites. The EWRs are considered interim due to the limited data set used to calibrate regional and wetland-specific modelling. Furthermore the water quality data presented within this study is considered baseline data only and has not been used in the determination of EWRs.

The environmental water requirements study comprised the following broad tasks:

- Selection of wetland sites within the Murray DWMP area;
- Desktop assessment of site-specific and desktop wetland ecological values and environmental management objectives;
- Survey of flora and mapping of vegetation communities for selected wetland sites.
- Survey of native fish, amphibians and baseline stygofauna survey for selected wetland sites;
- Identification of the water regime of selected wetland sites - using surface and groundwater data, and predicted water levels from wetland models provided by the DoW Water Science Branch;
- Determination of interim ecological water requirements of selected wetland sites;
- Prediction of the impacts of a range of climate change, development and drainage scenarios for the selected wetland sites;
- Mapping of the risk of impact for the selected wetland sites; and
- Development of monitoring and contingency plans for the selected wetland sites.

The methodology used in this assessment of interim regional-scale EWRs was adopted from the *Draft Guidelines for Ecological Water Requirements for Urban Water Management* (DoW 2009). The eco-hydrological range data for key Swan Coastal Plain wetland species were also considered in this EWR assessment following the methodology developed by Froend *et al.* (2004).

Wetland sites

The selection of wetlands sites was conducted via desktop assessment, site visits and stakeholder consultation. Site selection aimed at selecting sites that retained high ecological values as well as meeting other criteria. The wetland sites identified by their colloquial name for the Murray DWMP studies and their UFI number included:

- Barragup Swamp (UFI 3945);
- Benden Road (UFI 5724);
- Scott Road (UFI 5180);
- Elliott Road (UFI 7046);
- Airfield North and South (UFI 4835);
- Greyhound Road (UFI 5032); and
- Phillips Road (UFI 5056).

Ecological values

Ecological values and environmental objectives were identified through a desktop review of literature and available datasets, as well as site specific ecological surveys at each of the Murray wetland sites. The site specific ecological surveys included a wetland flora survey, native fish and amphibian survey and stygofauna baseline survey. The results from these surveys are summarised for each wetland and are detailed in supporting technical reports.

Water regime and determining interim EWRs

Surface and groundwater studies were undertaken to characterise the wetland water regime. The site specific studies included installation of PLIs and groundwater monitoring bores, including nested bores, at each wetland to monitor surface water levels and groundwater levels. Water quality data was also collected however this is considered baseline data only due to the limited dataset.

The wetland specific surface and ground water level data was used in conjunction with a regional groundwater level dataset to calibrate regional and wetland specific models by Department of Water staff. The output from the finer grid-scale wetland models was used in the EWR study to identify key components of the water regime and to determine EWRs for the selected wetland sites.

The EWRs for the selected wetland sites were described as the existing water regime components based on the modelled water level data for important aspects of the water regime including surface and groundwater minimum and maximum levels, magnitude of change in water levels and periods of drying and inundation. Interim regional-scale EWRs are identified for each of the wetland sites.

Scenario assessment and risk of impacts

The calibrated wetland models were used to determine the change to wetland water regimes under different land use, climate and drainage scenarios developed by the Department of Water. These scenarios were used to determine the percentage change in water levels compared to the base case current climate scenario.

The risk of impact for vegetation communities was identified along the vegetation transects established for each wetland site by assessing the percentage change in groundwater levels of climate change scenarios to the base case scenario. The risk of impacts are diplayed along the vegetation transects for each wetland site.

Monitoring requirements and future recommended work

It is recommened that monitoring of the wetland sites and regional groundwater bores is continued to improve baseline monitoring dataset for the wetland sites, to refine the interim EWRs and to monitor any changes in condition. Additional spring flora surveys are also recommended to monitor the condition of wetland vegetation.

Additional investigations, surveys and monitoring are required to revise the interim EWRs presented in this report at the regional scale. Further investigations will improve the level of confidence in the modelling data, improve the knowledge of the ecological values of the sites and provide additional water quality data to enable inclusion in revised EWRs.

Further site specific investigations are required to revise the interim regional scale EWRs to a level suitable for local and urban water management planning, for areas of future urban development adjacent to the selected Murray wetlands. Determination of the EWRs of other high value wetland sites located within or adjacent to proposed development areas is likely to be required. Guidance on the determination of specific water resource values should be sought from the Department of Environment and Conservation and Department of Water.

1. Introduction

1.1 Background

The Murray region has been identified by the Western Australian Planning Commission and local government authorities as a high priority for structure planning, which will provide guidance for future development and management of environmental issues.

Key to structure planning is the preparation of a drainage and water management plan (DWMP) that embraces water sensitive urban design and best management practices, and provides a framework for more site-specific water management plans. The DWMP will provide guidance on how water quantity and quality can be managed to minimise any adverse impacts on the environment and how to ensure sustainable development. As part of the planning process, a scientific understanding of surface and groundwater regimes and the ecological water requirements (EWRs) of selected wetlands is critical for identifying potential impacts on the natural environment.

GHD has been commissioned by the Department of Water (DoW) to undertake an EWR study of selected Murray wetlands. This study provides interim regional-scale EWRs, along with monitoring and contingency plans, for selected Murray wetland sites.

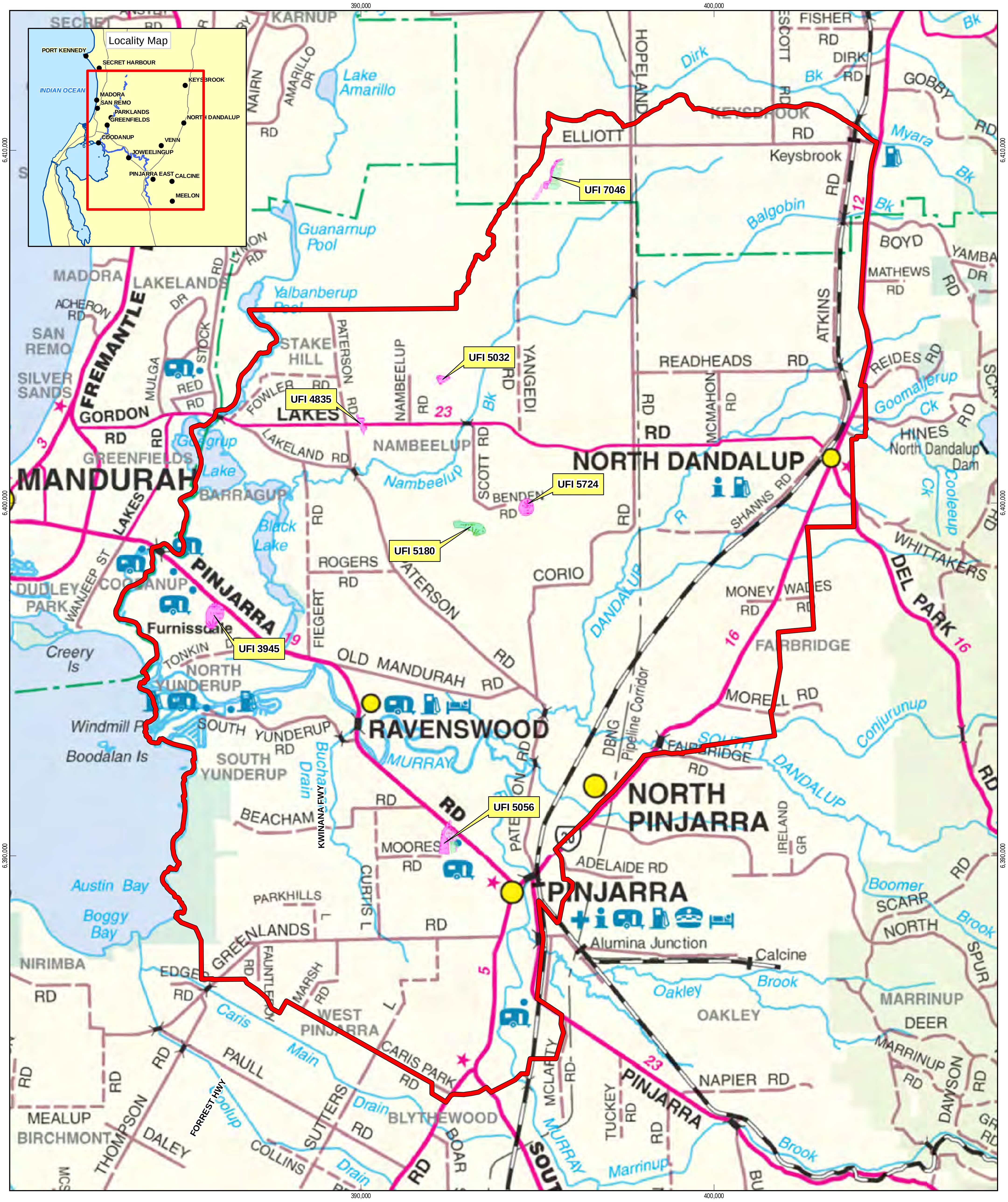
The EWRs are considered regional-scale as they correspond with strategic water management planning across a number of local government areas, and interim as they are based on limited site specific hydrological monitoring data. Furthermore the water quality data presented within this study is considered baseline data only and has not been used in the determination of EWRs. At the local scale further site specific investigations will be required (see Section 1.3.2).

This forms part of a wider multidisciplinary study undertaken to inform regional urban water management in the Murray DWMP study area. The DWMP study area extends from the Nambeelup Brook catchment in the north to the Fauntleroy Drain catchment in the south and from the Lower Serpentine River and Peel-Harvey Estuary in the west to the Murray River and Darling Range foothills in the east (Figure 1).

1.1.1 Ecological water requirements

Ecological water requirements refer to the water regime needed to maintain ecological values of water dependent ecosystems at a low level of risk (ARMCANZ and ANZECC 1996). A water regime is a prevailing pattern of water behaviour over a given time including components of water level, including change in levels, timing, duration and frequency. It may also include a description of water quality.

Determining ecological water requirements for a water dependent ecosystem involves identifying those aspects of the water regime that are most important for maintaining the identified ecological values and environmental objectives.The purpose of setting EWRs is to ensure maintenance of the ecological components of a water dependent ecosystem, including flora and fauna, hydrological functions and other ecological processes.



LEGEND

Study Area	**Geomorphic Wetlands**	Multiple Use
	Conservation	Not Assessed
	Resource Enhancement	Not Applicable

1:100,000 (at A3)

0 0.5 1 2 3 4 5

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 50

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Department of Water
Murray Drainage and Water Management Study

Job Number 61-2393706
Revision A
Date 02 SEP 2010

Geomorphic Wetlands Overview Map

Figure 1

G:\61\2393706\GIS\mxds\612393706-G004_Figure 1 - Geomorphic Wetlands Overview Map - QAd.mxd

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Data Source: DOW: Study Area - 20081202; Landgate (SLIP): Metro South 2009 Mosaic - SLIP 20090627; DEC: Geomorphic Wetlands, Swan Coastal Plain - 20070319. Created by: Nik Fadhil, xntan, jhchen

1.2 Study scope

The environmental water requirements study comprised the following broad tasks:

- Selection of wetland sites within the Murray DWMP area;
- Desktop assessment of site-specific and desktop wetland ecological values and environmental management objectives;
- Survey of flora and mapping of vegetation communities for selected wetland sites.
- Survey of native fish, amphibians and baseline stygofauna survey for selected wetland sites;
- Identification of the water regime of selected wetland sites - using surface and groundwater data, and predicted water levels from wetland models provided by the DoW Water Science Branch;
- Determination of interim ecological water requirements of selected wetland sites;
- Prediction of the impacts of a range of climate change and generic development scenarios for the selected wetland sites;
- Mapping of the risk of impact for the selected wetland sites; and
- Development of monitoring and contingency plans for the selected wetland sites.

1.3 Future work

1.3.1 Regional scale

The wetland EWRs in this study are considered regional-scale as they relate to strategic water management across local government boundaries and only a subset of the high value wetlands present within the study area were selected for inclusion in the DWMP. Additional investigations, surveys and monitoring are required to revise the interim EWRs presented in this report at the regional-scale. Further investigations will improve the level of confidence in the modelling data, improve the knowledge of the ecological values of the sites and provide additional water quality data to enable inclusion in revised regional-scale EWRs.

1.3.2 Local scale

Further site specific investigations are required to revise the interim regional-scale EWRs to a level suitable for local and urban water management planning, for areas of future urban development adjacent to the selected Murray wetlands. At the local scale determination of the EWRs of other high value wetland sites located within or adjacent to proposed development areas is likely to be required. Guidance on the determination of specific water resource values should be sought from the Department of Environment and Conservation and DoW.

2. Methodology

2.1 Overall approach to determine ecological water requirements

The methodology for this EWR study is adopted from the *Draft Guidelines for Ecological Water Requirements for Urban Water Management* (DoW 2009). This methodology comprises a number of steps, as outlined in Figure 2. The project scope involved Steps 1 to 5.

As the Murray DWMP is informing water management at a regional rather than local scale, a range of climate and generic development scenarios were assessed in lieu of Step 6 (urban water management design). An overview of the methodology (Steps 1 to 5) is provided below with site-specific detail provided in the following Sections. Appendix A provides a guide to the terminology.

Step 1 Identification of potential water dependent ecosystems through environmental characterisation of the subject land

This step involves environmental characterisation of the subject land and the surrounding area through collation and review of existing hydrological, geological and ecological resources. This is a common initial step for the environmental assessment of planning and development applications. The outcome of this step should include a description of the pre-development environment based on available data.

Step 2 Identify water dependent ecosystems and establish their conservation significance

The outcome of this step is to identify conservation significant water dependent ecosystems that may be directly or indirectly impacted by the proposed development. These are the water dependent ecosystems that will be the focus in the determination of ecological water requirements.

Step 3 Identify environmental objectives of water dependent ecosystems

The outcome of this step is to set environmental objectives to ensure that essential ecological values of the water dependent ecosystems are maintained. Identifying the environmental objectives in the earliest planning stages allows the identified ecosystem attributes to be incorporated and provides a basis from which to measure success through monitoring.

Step 4 Identify the current water regime

The outcome of this step is to identify the current water regime. This step is required to demonstrate an understanding of the existing conditions and to assess the proposed urban water management design.

Step 5 Determine the ecological water requirement required to maintain environmental objectives

The outcome of this step is to determine the ecological water requirement to maintain the key environmental objectives (Step 3). The ecological water requirement should be defined as measurable hydraulic and hydrological variables and their limits of acceptable change, for the key components and processes of the water dependent ecosystem. These variables may then be used to monitor the compliance of the proposed urban water management design. The limits of acceptable change of water regime attributes should be defined based on sound environmental arguments.

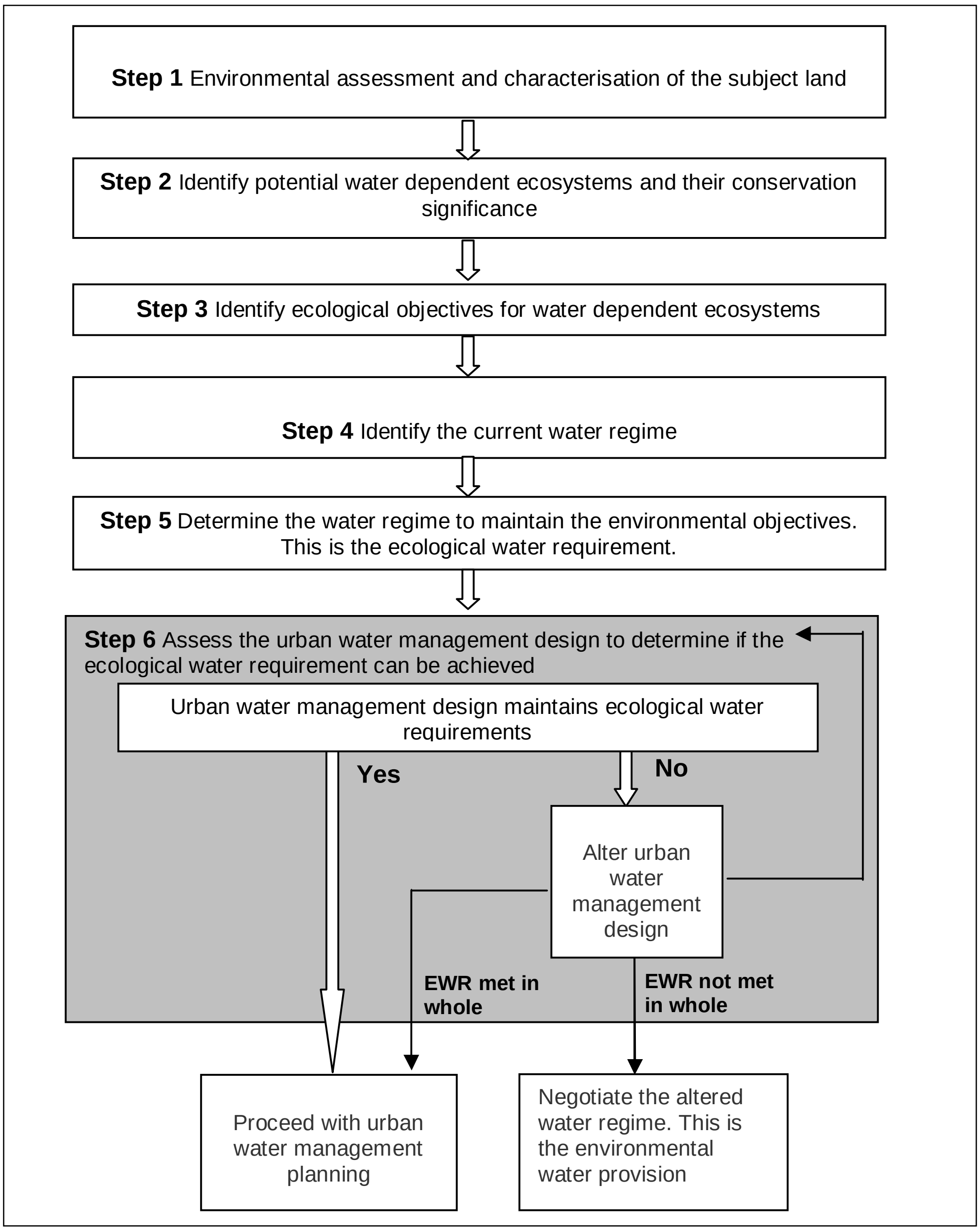


Figure 2 Process for determining ecological water requirements for water dependent ecosystems for urban water management (from DoW 2009)

2.2 Environmental characterisation of the study area (Step 1)

Environmental characterisation of the Murray DWMP area was conducted via desktop review of available literature and the following databases:

- Geomorphic Wetlands Swan Coastal Plain dataset;
- Environmental Protection Policy (EPP) areas;
- Department of Environment and Conservation (DEC) Estate;
- Bush Forever;
- Flora, Fauna and Threatened Ecological Community database searches (DEC);
- NatureMap database;
- Department of the Environment, Water, Heritage and Arts (DEWHA) database for flora and fauna listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act);
- Directory of important wetlands in Australia.

2.3 Selection of study sites (Step 2)

2.3.1 Identification of water dependent ecosystems in the Murray DWMP area

The wetland selection process for the EWR analysis involved key members of the EWR project team including:

- Representatives from the Wetlands Section of the DEC;
- Representatives from the Drainage and Waterways Branch, the Environmental Water Planning Branch, the Water Science Branch and the Mandurah regional branch of the DoW; and
- Representatives from GHD.

Local landowners and their environmental consultants were also involved in the selection process.

A desktop assessment of wetlands in the Murray DWMP area was conducted using aerial photography and classification from the DEC's Geomorphic Wetland Swan Coastal Plain dataset. Wetlands classified "conservation category" (CCW) were prioritised according to their high remnant ecological values, while wetlands classified "resource enhancement" were considered if they had high potential ecological values. The desktop assessment included a review of the databases identified in Section 2.2 as well as the Department of Indigenous Affairs Aboriginal Heritage database. The desktop assessment was followed by a site investigation of the preliminary selection of wetlands in June 2008.

Additional wetland visits were conducted in April 2009 via consultation with local landowners in an attempt to select wetlands from a range of soil types, and hydrological locations. A number of issues including degradation, site access permissions and drilling permissions restricted the selection of wetland sites.

Wetlands were selected on the following basis:

- They were high ecological value, as agreed by stakeholders and as appropriate to the EWR study;
- They were accessible by drill rig;
- Land access and drilling permissions could be obtained; and
- They were within the Murray DWMP study area.

Furthermore, a linear wetland comprising a section of the Dandalup River was selected for the EWR study by the allocation branch of the DoW.

Precluded from this study were:

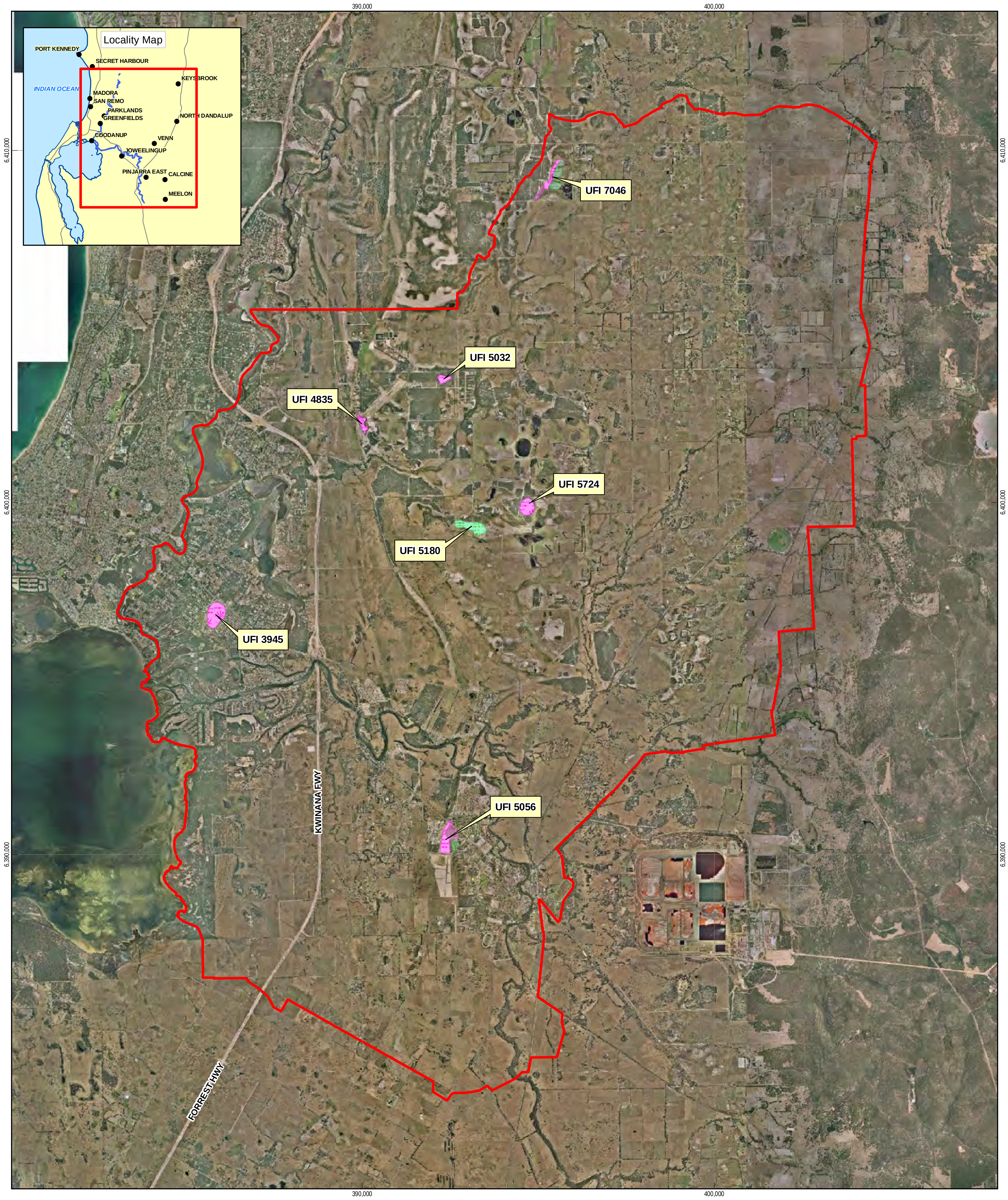
- Wetlands with a dampland classification, as no sites satisfied the criteria due to the widespread clearing of the study area;
- Wetlands containing remnant vegetation along the Murray river floodplains, due to poor quality vegetation or site access issues; and
- The Peel-Yalgorup wetlands, as they are located along rivers, have larger catchments than defined by the Murray DWMP area and were unable to be modelled in the current study.

The DEC Geomorphic Wetland Swan Coastal Plain dataset identifies each wetland on the Swan Coastal Plain with a four digit unique feature identifier (UFI). The selected wetlands are identified by their UFI from the geomorphic wetlands dataset, and by the colloquial name allocated for the Murray DWMP project. Table 1 lists the Murray wetland sites selected for this interim regional-scale EWR assessment and

Figure 3 shows their locations.

Table 1 Selected Murray wetland sites

Wetland UFI	Wetland name	Management category	Wetland classification
3945	Barragup Swamp	Conservation	Sumpland
5724	Benden Road	Conservation	Sumpland
5180	Scott Road	Resource enhancement	Sumpland
7046	Elliott Road North	Conservation	Sumpland
7029	Elliott Road South	Conservation	Palusplain
7027		Resource enhancement	Palusplain
7028		Resource enhancement	Palusplain
4835	Airfield North	Conservation	Sumpland
	Airfield South		
5032	Greyhound Road	Conservation	Sumpland
5056	Phillips Road	Conservation	Palusplain
5055		Conservation	Dampland
5195		Conservation	Palusplain
5196		Resource enhancement	Dampland
5198		Resource enhancement	Palusplain
5200		Conservation	Palusplain



LEGEND

Study Area

Geomorphic Wetlands

Conservation

Resource Enhancement

Multiple Use

Not Assessed

Not Applicable

1:100,000 (at A3)

0 0.5 1 2 3 4 5

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 50

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Murray Drainage and Water Management Study

Job Number	61-2393704
Revision	A
Date	30 AUG 2010

Aerial Overview of Wetland Locations

Figure 3

G:\61\2393706\GIS\mxds\612393704-G003_Figure 3 - Aerial Overview of Wetland Locations - QAd.mxd

GHD House, 239 Adelaide Terrace Perth WA 6004 **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Data Source: DOW: Study Area - 20081202; Landgate (SLIP): Metro South 2009 Mosaic - SLIP 20090627; DEC: Geomorphic Wetlands, Swan Coastal Plain - 20070319. Created by: Nik Fadhil, xntan, kdiralu, Csun, jhchen

2.4 Identification of ecological values and environmental objectives (Step 3)

2.4.1 Ecological values

Ecological values for water dependent ecosystems are derived from site specific information. Ecological values are typically derived from vegetative and floristic components of the ecosystems as these are generally more easily defined and measured than other transient components. Where adverse impacts occur to the vegetation and flora of an ecosystem, these generally result in changes to the associated fauna assemblages (Murray *et al*. 2003).

Ecological values for vegetative and floristic attributes may include: key species, vegetative form (i.e. forest, woodland, shrubland, herbland), distribution of overstorey and understorey components, species richness, and species mortality rates.

2.4.2 Environmental objectives

An environmental objective is an operational goal for managing a part of the environment. Environmental objectives are derived from site-specific ecological values. In some cases, environmental objectives for an ecosystem may relate to specific species (i.e. Declared Rare Flora, endangered fauna); alternatively the environmental objectives may relate to maintaining key ecosystem processes that rely on some aspect of the water regime.

Following the approach of Jamieson and Boyle (2001), the initial step in setting environmental objectives is stating the concepts in general terms that can be understood by a broad audience, followed by identifying measurable attributes of the water dependent ecosystem against which future monitoring may be established.

Examples of conceptual environmental objectives include:

- 'to maintain or preserve water-dependent ecosystem attributes and functions';
- 'to improve or enhance the water-dependent ecosystem attributes and functions'; and/or
- 'to maintain biodiversity'.

Examples of operational environmental objectives (after Froend and Loomes 2006) include:

- 'to maintain species composition';
- 'to maintain species distribution';
- 'to maintain species richness';
- 'to control species mortality'; and/or
- 'to maintain species vigour'.

Environmental objectives are often set for either a vegetation community or for identified vegetative components of the ecosystem. This is because vegetative components are important in the provision of ecosystem services and are more easy to define and measure than transient components.

2.4.3 Identification of ecological values and environmental objectives for selected wetlands in the Murray DWMP area

Ecological values and environmental objectives were identified through the desktop review and site specific ecological surveys at each of the Murray wetland sites. These supporting technical survey reports included:

- *Wetland flora study* (GHD in preparation);
- *Native fish and amphibian survey* (GHD in preparation); and
- *Stygofauna baseline survey* (GHD in preparation).

Wetland flora study

A summary of the vegetation and flora survey report (methodology) for the selected Murray wetlands is given below. Site-specific vegetation data is provided in the individual wetland chapters that follow.

A spring flora survey was completed by qualified GHD botanists between 2-12th November 2009. Additional site visits were conducted at some wetlands that were flooded in sections during the initial survey period. The spring flora survey was undertaken with reference to Guidance Statement 51, guidelines for *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia* (EPA 2004).

Quadrats (10 x 10 m plots) were placed along selected vegetation transects at 10 cm change in the surface height. Due to rapid elevation changes at some wetlands the 10 x 10m quadrats were not able to be located at every 10cm change in surface height, and quadrats were located approximately every 20m along the transect line. This change to the initial methodology was discussed with and approved by DoW in response to site conditions.

Data collected for quadrat locations included spot surface height values at each community boundary, a flora species list, with heights and percent cover recorded, and the length of transect occupied by each vegetation type. Vegetation description and condition were assessed. Habitat, soil, bare ground, logs, twigs, leaves, disturbance types and weeds and age since fire were also recorded. Changes in vegetation types were recorded along the transect using a GPS.

The vegetation condition within the quadrats was assessed using the vegetation condition rating scale developed by Keighery (1994) that recognises the intactness of vegetation, which is defined by the following:

- Completeness of structural levels;
- Extent of weed invasion;
- Historical disturbance from tracks and other clearing or dumping; and
- The potential for natural or assisted regeneration.

Native fish and amphibian survey

A summary of the native fish and amphibian survey report (methodology and results) for the selected Murray wetlands is given below and site specific data is provided in the individual wetland chapters that follow.

Native fish sampling was undertaken in August 2009, and included an opportunistic fauna survey (i.e. did not involve trapping). The native fish sampling method involved two people netting for a 30 minute period, as per similar methodology used to survey for Black-stripe Minnow (*Galaxiella nigrostriata*) (Kim Williams pers comm.). Selected sample points were chosen at each wetland with a minimum of 1 hour spent using hand fish nets. The nets are 50 cm equal sided triangular frame with a gauge mesh of 3 mm. Nets are placed in the water and used in a figure 8 motion in front of the body while slowly walking around the study area. Different depths are sampled during this process.

Amphibian sampling commenced in July 2009 with all wetlands visited by early August. The autumn amphibian survey was undertaken at the time of writing and results will be reported in the *Native fish and amphibian survey report* (GHD in preparation). The amphibian survey involved aural recording of amphibian species as well as opportunistic sighting of active non-calling amphibian species. Established study points were visited at night and species calling over a 10 minute period were recorded. Abundance of species is measured by ranking the level of calling per species. The ranking system is listed as follows:

- 0- no calling recorded,
- 1- Individuals calling and can be counted,
- 2- calls overlap but individuals can be counted, and
- 3- calls overlap and individuals can not be counted or distinguished (full chorus).

Native fish were not captured at any of the wetlands, however many water invertebrates and tadpoles were captured. Most of the wetlands in the area are ephemeral with seasonal inundation. The absence of fish species within these wetlands may result from the lack of permanent water. However some Gallaxid species are known to aestivate in the mud once water systems dry up. In the Murray wetlands that were surveyed for fish species the time frame between drying and refill may be too great and may therefore not be suitable for native fish species.

Seven of the thirteen possible species of amphibians were recorded over the eight wetlands during the sampling period. *Crinia insignifera* is an endemic species to Western Australia and primarily lives on the Swan Coastal Plain; this species was the most prolific recorded occurring at all wetlands with an abundance ranging from 1 to 3. *Litoria adelaidensis* was found in seven of the wetlands but had a lower abundance rating of 1 and 2, reaching a rating of 3 at only one site. The remainder of the frog species *Crinia georgiana, Crinia glauerti* and *Pseudophyne guentheri* were found at five, five and three sites respectively and had fluctuating scores of 1 to 3. The least common calling was from *Lynodynastes dorsalis* which was only recorded at two sites with an abundance of 1.

Amphibians not recorded calling in July and August were species that have breeding events in the autumn season and were therefore not recorded unless observed active at the wetlands. One of these species was *Heleioporus eyrei* which was observed active at two sites however was not recorded calling.

Stygofauna baseline survey

A summary of the stygofauna baseline survey report (methodology and results) is given below.

The purpose of the stygofauna study was to provide a baseline stygofauna survey of the superficial aquifer within the Murray area, an area which has never previously been sampled for stygofauna. Sampling for stygofauna was undertaken during a single phase in February 2010. Nineteen (19) water bores in the vicinity of six wetlands within the Murray drainage were sampled for the presence of stygofauna. The nearby wetland sites included Wetland UFI 3945 (Barragup Swamp), Wetland UFI 4835 (Airfield Wetland), Wetland UFI 5032 (Greyhound Road), Wetland UFI 5056 (Phillips Road), Wetland UFI 5724 (Benden Road) and Wetland UFI 5033 (Lakes Road). In addition monitoring bore HS-097, a regional long term monitoring bore located on Lakelands Road was sampled. Bores sampled were between 3.6 – 71 m deep, with an average depth of 15.6 m.

Two of the 19 bores sampled yielded stygofauna (11%). A single species of cyclopoid copepod was recorded from bore HS108-2A and two species of Parabathynellidae? were recorded from bore HS099-1A. The survey recorded two copepod individuals and approximately 50 Parabathynellids from the two bores, ranging from adults to juveniles. These bores intersect the superficial alluvial aquifer above the Leederville Aquifer and are slotted with 0.4 mm slots. No other stygofauna was recorded from any bores sampled during the regional survey. The stygofauna species recorded are currently undergoing further identification.

2.5 Identification of the water regime (Step 4)

2.5.1 Surface water level monitoring

Surface water monitoring was conducted at individual wetland sites through installation of peak level indicators (PLI's). Surface water levels at the PLI's were monitored by personnel from the Mandurah regional branch of the DoW on a monthly basis from August 2009 to December 2009 for most wetlands. The monitoring will continue until at least June 2011.

2.5.2 Groundwater level monitoring

Shallow groundwater monitoring bores were installed at the selected wetland sites to Department of Water specification. Water levels were monitored by personnel from the Mandurah regional branch of the DoW on a monthly basis beginning June 2009 to December 2009. The monitoring will continue until at least June 2011.

2.5.3 Water quality monitoring

Water quality is an important component of the water regime of water dependent ecosystems. Water quality monitoring was undertaken by personnel from the Mandurah regional branch of the DoW. Wetland water quality monitoring comprised surface water monitoring of physiochemical parameters (EC and pH) on a monthly basis between August and December for most wetlands, with a single snapshot monitoring event for nutrients and other water quality parameters in September 2009.

The water quality monitoring data is considered baseline data only. Physiochemcial and nutrient data is reported for the selcted wetlands however due to the limited nature of the datset it has not been considered in determining interim EWRs.

2.5.4 Regional scale surface water/groundwater modelling and wetland modelling

The Water Science Branch of DoW undertook regional and wetland specific modelling work for the EWR component of the DWMP studies. This included:

- Characterisation and conceptualisation of the wetlands included in the EWR study. This involved the determination of the appropriate drivers for wetland water levels, based on available literature and data gathered from hydrogeological data and stratigraphic interpretation from the drilling programme undertaken by GHD. This project phase was described in the “Conceptual model report” (Hall *et al.* 2010a).

- Construction and calibration of finer grid-scale wetland models using modelling results from the surface water and groundwater studies. Detailed calibration of fine-scaled models was completed using data collected during the 2009 winter by Department of Water staff. Boundary conditions for wetland models were taken from the Murray regional model. This phase was described in the “Construction and calibration report” (Hall *et al.* 2010b).

The output from the wetland scale modelling was used in the current study for determining EWRs for the selected wetland sites. The data comprised groundwater level data (daily groundwater heads) reported along wetland transects established for each wetland site, comprising specific transect point locations, vegetation community locations and the lowest surveyed point along the selected wetland transects.

2.5.5 Description of water regime

The predicted water level data from the wetland scale models (Section 2.5.4) were used in the determination of the water regime for the site specific wetland sites. The assumptions and errors associated with the predicted model data are outlined in the associated modelling reports by the Water Science Branch (Hall *et al* 2010 a).

2.5.5.1 Water levels

The surface and groundwater water levels for individual wetland sites were derived from the calibrated base case scenario, with modelled water levels for the period 1978-2009. The modelled water record was examined for the available range (1978-2009) as well as for 20 (1990-2009), 10 (2000 – 2009) and 5 (2005 – 2009) year periods in order to consider the water regime relevant to vegetation species with different lifespans (Loomes 2000). The water level EWR was described as the peak and annual average maximum and minimum water level as the timing of maximum and minimum water levels.

2.5.5.2 Period of drying

The period of drying was calculated as the longest modelled period of consecutive days with dry readings for the lowest surveyed point along the wetland transect. In some instances the modelled data shows the wetland as drying, rewetting and then drying again. The longest of these drying periods is used in this assessment.

2.5.5.3 Magnitude of change

The magnitude of change in water level was determined from the modelled data for the lowest surveyed point of the wetland, considering both surface and ground water. The parameter used in this assessment refers to the interannual magnitude of change in minimum and maximum water level. This parameter is considered important in order to ensure that that the prevailing pattern of water level change (as seasonal fluctuations in minimum and maximum levels) is maintained, and the wetland water level is not regulated by potential future development. Regulation of wetland water level through water management and drainage has the potential to reduce the variability in water level fluctuation which may affect wetland community dynamics and biodiversity.

The magnitude of change was calculated as the largest difference between the minimum (or maximum) water level between consecutive years of the modelled record, and is reported as the largest increase and largest decrease in the minimum or maximum water levels between years (Figure 4).

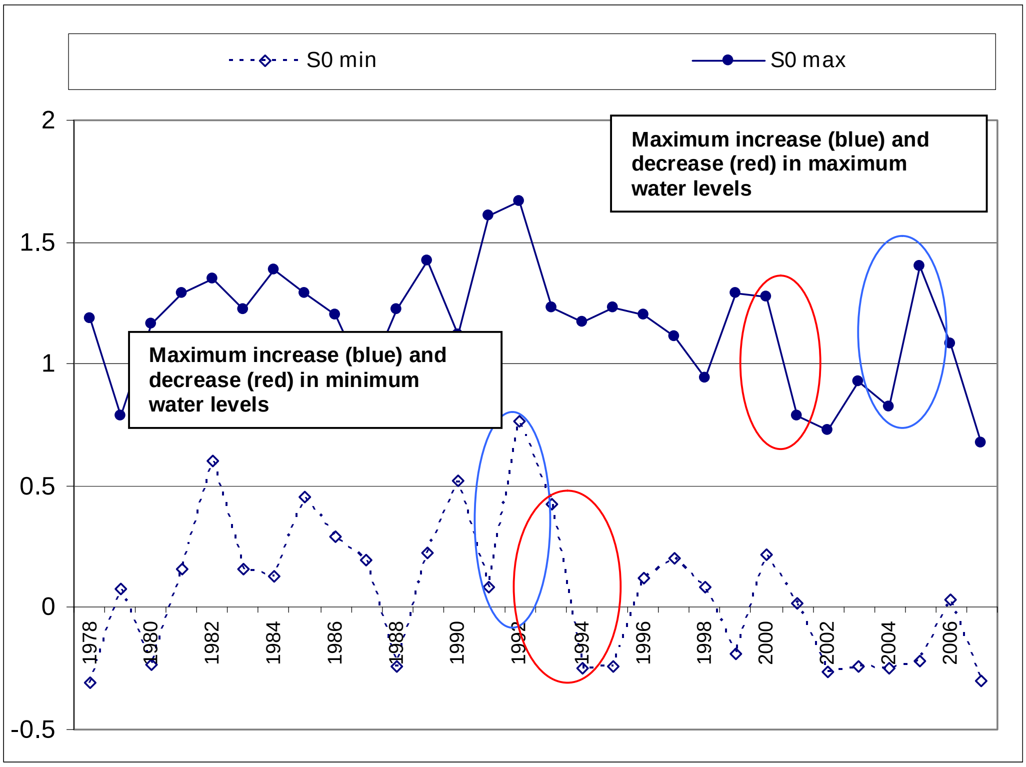


Figure 4 **Example of magnitude of change analysis for maximum and minimum water levels for Barragup Swamp (S0 - Base case scenario)**

2.6 Determination of ecological water requirements (Step 5)

This assessment of interim EWRs for Murray wetlands considers the water requirements of vegetative components, following the methodology developed by Edith Cowan University (Froend and Loomes 2004), and compares these to the existing water regime of the wetlands based on the modelled data provided by the Water Science Branch of DoW.

The EWRs of the vegetative components of the ecosystem were considered on the premise that maintenance of the existing water regime that sustains vegetation and flora of the site will also maintain habitat for the majority of fauna and for key processes such as sediment nutrient cycling, flood mitigation and other hydrological functions. A review of the suitability of using vegetative ecosystem components for determining wetland ecosystem EWRs by GHD is provided in Appendix B.

2.6.1 Ecological data

The ecological survey work (See Section 2.4.3) identified vegetation and flora species and community types, the vegetation condition and rating and the elevation ranges over which they occur at the site.

2.6.1.1 Eco-hydrological data

Data on the known eco-hydrological ranges for key species common to wetlands in the south-west of Western Australia was sourced from the following documents:

- Froend and Loomes (2006) *Determination of ecological water requirements for wetland and terrestrial vegetation – southern Blackwood and Scott Coastal Plain*
- ENV. Australia (2007) *Ecological water requirements - Forrestdale Main Drain*
- Ecoscape (2007) *Ecological water requirements of selected wetlands within the Peel Main Drain catchment*

The eco-hydrological ranges of key species common to south-west wetlands were tabled for each community type. These were referred to as indicator species. Where there were no species with known eco-hydrological ranges for a particular vegetation community type it was considered that maintenance of the existing water regime would provide protection of the community.

2.6.1.2 Eco-hydrological water level range

Using available indicator species the eco-hydrological range in water levels were determined for the selected wetland vegetation community types following the method of Froend and Loomes (2006). The mean, south-west[1], maximum and minimum water levels of the indicator species were subtracted from the upper and lower elevation extent of each vegetation community to provide the following eco-hydrological range of water levels for the community:

- *Upper maximum water level* (U max WL in mAHD) = upper elevation gradient for vegetation community (in mAHD) - SW mean maximum water depth (m);
- *Lower maximum water level* (L max WL in mAHD) = lower elevation gradient for vegetation community (in mAHD) - SW mean maximum water depth (m);
- *Upper minimum water level* (U min WL in mAHD) = upper elevation gradient for vegetation community (in mAHD) - SW mean minimum water depth (m); and
- *Lower minimum water level* (L min WL in mAHD) = lower elevation gradient for vegetation community (in mAHD) - SW mean minimum water depth (m).

Figure 5 displays the Upper maximum and Lower minimum water levels for vegetation species *Melaleuca rhaphiophylla* of vegetation community Mr of Barragup Swamp, at the upper and lower elevation extent of the vegetation community.

[1] The south-west water levels refer to the known eco-hydrological range (maximum and minimum water level) data for key south-west vegetation species with available data . These are based on previous studies of maximum and minimum water ranges (Section 2.6.1.1)

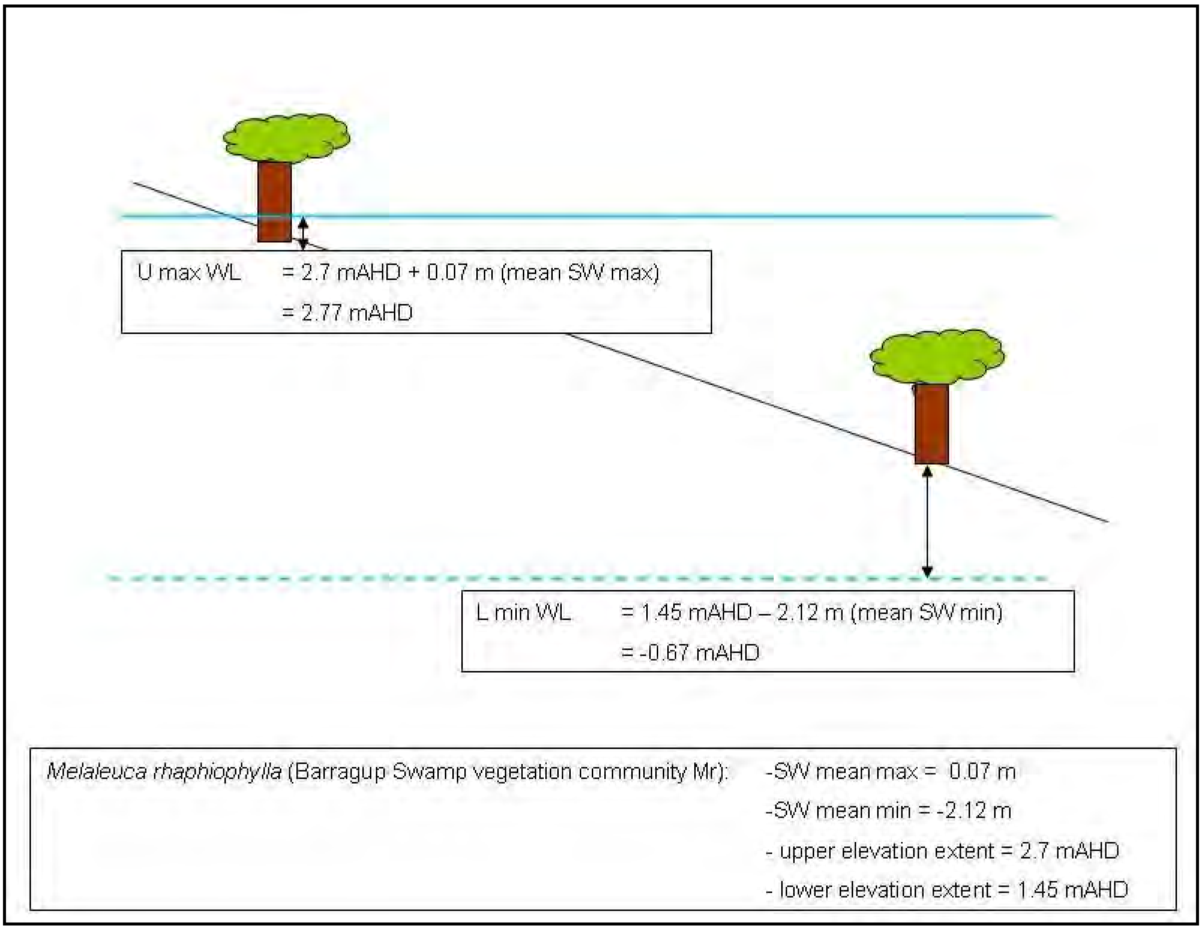


Figure 5 Example diagram showing the application of eco-hydrological range approach to EWR (SW max and SW min DTG) as applied to vegetation communities in the Murray DWMP area

2.6.1.3 Approach

The most vulnerable of the indicator species was selected to define the range of water levels for each individual community type. This method excludes terrestrial tree species unless they were the only available indicator species. This method assumes that maintenance of the eco-hydrological water levels of the most vulnerable species will maintain the biodiversity, composition and abundance of the vegetation community. The range of water levels were compared to the last 10 years (2000-2009) of calibrated model output data for the upper and lower elevation extent of the vegetation community.

2.6.1.4 Limitations

The eco-hydrological range database is held by Edith Cowan University and is reviewed and updated as additional data become available. The full eco-hydrological range database is not publically available and therefore the data used here may no longer be current.

A further limitation of this method is that all species within a community are recorded as occurring along the entire elevation range of that community. This is not a major issue for those communities that occur over a limited elevation gradient however it may not accurately represent the eco-hydrological range of species within communities that occur across a greater elevation range. Furthermore only those species that occur within the representative quadrats along the vegetation transects at each site were considered. This may not meet the ecological water requirements of uncommon or unidentified species.

2.6.2 Ecological water requirements

The ecological water requirements for selected wetland sites were determined from the water regime data based on the wetland model predictions (See Section 2.5.5). The ecological water requirements were described as the existing water regime components based on the modelled water level data for important aspects of the water regime including surface and groundwater minimum and maximum levels, timing of minimum and maximum water levels, magnitude of change in water levels and periods of drying and inundation.

It was not possible to set limits of acceptable change for the different components of the water regime due to the limited data used to determine the interim EWRs. As with the interim EWRs this should be reviewed following additional monitoring of the site specific hydrology and ecology of the sites. The EWRs based on the water regime are also discussed in relation to the water requirements identified for the vegetation communities based on the available eco-hydrological data (see Section 2.6.1.1).

2.7 Scenario Assessment and Risk of Impact Mapping

2.7.1 Scenario Assessment

The calibrated model was used to calculate the water regime for a number of different scenarios. A suite of predictive runs were undertaken to determine the change to water budgets and wetland water levels under various land use, climate and drainage scenarios. Scenarios were presented to the Water Science Branch of DoW by GHD and by the Drainage and Waterways Branch of the DoW. The list of scenarios was approved by the Murray DWMP Technical Advisory Group.

The list of wetland scenarios developed by the Water Science Branch of DoW is displayed in Table 2and described below. The scenarios are further described in the "*Land development, drainage and climate change scenario report*" (Hall *et al*. 2010c). This output was used in the current study for assessing the change in water regime and risk of impacts for the selected wetland sites for the different scenarios.

Table 2 List of wetland scenarios for Murray wetlands

Scenario ID	Scenario name	Climate	Sub-surface drainage	Other changes
EWR_S0	Base case	Current	No drains	No change
EWR_S1	Sand dune analysis	Current	No drains	Without sand dune
EWR_S2	Hydrologic zone analysis (AAMaxGL)	Current	Drainage at AAMaxGL	Hydrologic zone analysis
EWR_S3	Hydrologic zone analysis (0.5m)	Current	Shallow – 0.5m BGL	Hydrologic zone analysis
EWR_S4	Hydrologic zone analysis (1m)	Current	Medium – 0.5m BGL	Hydrologic zone analysis
EWR_S5	Wet climate	Wet	No drains	No change

Scenario ID	Scenario name	Climate	Sub-surface drainage	Other changes
EWR_S7	Dry climate	Dry	No drains	No change
EWR_S8	Historical wet climate	Historical wet	No drains	No change
EWR_S9	Sea level rise	Current	No drains	0.9m sea level rise

2.7.1.1 Base case scenario (S0)

The base-case scenario (S0) represents current conditions. The base case scenario was simulated over the 30-year period between the years 1978 – 2007 (with an additional 5 years of model spin-up period from 1973 – 1978). A detailed description of the base case model parameters and water balance is presented in the *Construction and Calibration Report* (Hall *et al.* 2010b).

2.7.1.2 Sand dune analysis (EWR_S1)

Fringing sand dunes are believed to be drivers of wetland water levels. Localised groundwater mounds that form beneath sand dunes that border wetlands are understood to increase both the wetland water levels and the duration of wetland inundation. Sand dunes are useful in urban development, as they provide fill for development foundations which is cost-effective and locally available. The sand dune analysis scenario (EWR_S1) aims to identify the wetlands with significant sand dunes; and to then use the model to compare the changes in wetland water levels and duration of inundation with and without the dunes, thus providing a quantitative approach to determining the significance of the fringing sand dunes on the wetland hydrology.

Two wetland models had wetlands with significant fringing sand dunes; the Lakes Road model and the Scott Road model. The sand dune analysis scenario was run for the same climate sequence and boundary conditions as the base case model. The only changes to the base case scenario (EWR_S0) were the changes in model topography. Therefore, any change in wetland hydrology can be attributed to a change in the topography associated with the sand dunes, rather than a change in recharge and infiltration rates resulting from a land use change.

2.7.1.3 Hydrologic zone analysis (EWR_S2, EWR_S3 and EWR_S4)

Hydrologic zones are designed to protect wetlands from potential impacts of drainage while helping safeguard and maintain ecological processes and functions within the wetland. A hydrologic zone differs from an ecological buffer and is defined as an area where installation of groundwater drainage systems may have an undesirable hydrological influence on the wetland. Hydrologic zones vary with topography, geology, hydrogeology and the presence of drainage infrastructure. Hydrologic zone extent can be more or less extensive than ecological buffers. The hydrologic zone extent is measured from the outside extent of wetland dependant vegetation (the wetland function area) to the edge of any proposed development or activity.

Sub-surface drainage can lower the water table, and adversely affect the hydrology of wetlands (lower water levels and decreased periods of inundation). However, the magnitude of the effect of the subsurface drainage system is likely to depend on the extent of the hydrologic zone, the level of the sub-surface drains, and the natural hydrological regime of the wetland.

The wetland hydrologic zone analysis scenarios (EWR_S2, EWR_S3 and EWR_S4) explore the effects of various drainage levels and hydrologic zone extents on the wetland water regimes. The objective of the scenario is to quantify the effect hydrologic zones of various extents on the hydrological regime of the wetland, for various sub-surface drainage levels.

2.7.1.4 Climate scenarios (EWR_S5, EWR_S7 and EWR_S8)

For each of the wetland models, the base case scenario (EWR_S0) was simulated using SILO rainfall and evapotranspiration data for the years 1978 – 2007. This time period corresponded to the years 2010 – 2039 for the future climate scenarios.

- The wet climate scenario (EWR_S5): -1.43% change in mean annual rainfall from 1975 – 2007 (GCM NCAR-PCM, warming scenario 1°C)
- The dry climate scenario (EWR_S7): -16.18% change in mean annual rainfall from 1975 – 2007 (GCM MRI, warming scenario 1.3°C)
- The historical wet climate sequence (EWR_S8): used SILO data from 1945 – 1974, which corresponded to a 14.9% increase in mean annual rainfall compared to the period 1978 – 2007.

2.7.1.5 Sea level rise (EWR_S9)

The sea level rise scenario was only undertaken for wetland models that were identified as being affected by sea level rise in the regional model. The only wetland from the EWR study affected by sea level rise is Barragup Swamp. The sea level rise scenario was modelled for Barragup Swamp by increasing all model boundaries from 0 mAHD to 0.9 mAHD. All other model inputs and parameters were identical to EWR_S0.

2.7.2 Reporting of Wetland Scenario Results

The results of the wetland scenario analysis were assessed based on the percentage change from the base case scenario. The results of the sand dune and hydrologic zone analysis wetland scenarios are taken from Hall *et al.* (2010c). Assessment of the wetland scenarios by GHD has focused on the climate change scenarios for which model output was provided by the Water Science Branch of DoW. The assessment of climate change scenarios compared the annual average minimum groundwater level (AAMinGL) and annual average maximum ground water level (AAMaxGL) for the climate change scenarios against the base case scenario for the lowest point along the vegetation transect. The following time periods for climate change scenarios were considered:

- EWR_S5 and EWR_S7 (1978-2007); and
- EWR_S8 (1950-1974).

The assessment of scenarios compares the absolute change in wetland water level in metres above ground level (mAGL) and metres below ground level (mBGL). The relative change in water level is more important than the absolute change. For example, a wetland with an average maximum depth of 1.0 m, a 0.1 m change from the base case scenario will result in 10% change, whereas a wetland with an average maximum depth of 0.5 m a 0.1 m change will result in a 20% change from the base case. The impact on the wetland was considered to be low where the change in minimum and maximum water level, compared to the base case scenario, was less than 10%. This is based on the risk of impact methodology described in Section 2.7.3.2.

2.7.3 Risk of Impact

2.7.3.1 Background to Risk of Impact

A method to determine the risk of impacts from existing and potential water regimes for terrestrial and wetland vegetation was developed by Froend *et al.* (2004) for wetlands on the Gnangara and Jandakot Mounds, and further refined by Froend and Loomes (2006) and applied to other south-west wetlands. This method uses a number of criteria to establish the risk of impact to a water dependent ecosystem and its key ecological values and objectives. These criteria include:

- The conservation value of the wetland site;
- Current depth to groundwater; and
- Historic groundwater level change.

The conceptual model developed for wetland vegetation is shown in Appendix E. To date this method has been applied to assess the risk of impact to water dependent ecosystems where the primary risks are presented from drawdown, or groundwater decline. In a review of the potential impacts of Managed Aquifer Recharge on water dependent vegetation (Dillon *et al.* 2009) it was identified that while wetlands are generally less susceptible to rising water levels due to greater species tolerance of inundation, there is a lack of research available to make meaningful conclusions. The review suggests that application of the inverse of the method of Froend and Loomes (2006) was not unreasonable, also suggesting that greater levels of rise may be tolerated compared to corresponding levels of decline.

Naumburg *et al.* (2005) developed conceptual models for phreatophytic vegetation response to increasing and decreasing water levels (Appendix E). The models identify that a small change[2] in water level is not likely to have a measurable effect (low risk of impact) and a stable community would remain for both the increasing and decreasing water level scenarios.

2.7.3.2 Risk of Impact Methodology

For the Murray wetland systems the risk of groundwater decline is present due to climate change. Further risks are presented by the potential increase in surface and ground water levels due to climatic influence as well as management of urban drainage.

The risk of impact analysis identifies the magnitude of change in annual average water levels between the base case and the scenario data as % change from the base case, with the corresponding level of risk. For the purposes of this assessment the level of risk was determined with regard to ANZECC (2000)[3], Naumberg *et al.* (2005) and the framework developed by Froend *et al.* (2004) for the magnitude of groundwater level change for the wetlands on the Gnangara Mound. It is important to note that further work is required to identify the risk of impact associated with changes in water level, as well as other aspects of the water regime, and the current method is an attempt to incorporate available scientific information. Using this methodology the following risks have been identified:

- Low risk: No measurable effect / small change or stable community.
- Moderate risk: Some sensitive species may be impacted but majority of species remain / moderate shift in community composition and structure.

[2] The magnitude of what is considered a ‘small change’ was not quantified by Naumburg *et al.* (2005)

[3] ANZECC (2000) refer to ‘no change’ as a statistically conservative change from baseline or median value, e.g. change of 10% or one standard deviation from a baseline mena.

- High risk: Only resilient species remain and new community type may form in the long term / major shift in community composition and structure.

The risks and corresponding % change in water levels are displayed in Table 3.

Table 3 Risk of impact to Murray wetlands

Change in annual average minimum and maximum water level[4]	% change from base case water level	Risk of impact
Small / no change	0 – 10%	Low
Moderate	10 – 20 %	Moderate
Large	> 20%	High

2.7.4 Susceptibility and Risk of Impact Mapping

The risk of impact was assessed for the vegetation communities identified along the vegetation transects for the Murray wetland sites. The risk of impact assessment was undertaken in the same manner as the assessment of climate change scenarios. This was done by comparing the annual average minimum groundwater level (AAMinGL) and annual average maximum ground water level (AAMaxGL) for the climate change scenarios against the base case scenario. This was done for the vegetation community change locations located along the wetland transects by comparing the climate change scenario to the base case at the upper and lower elevation extents of the vegetation community.

It should be noted that this methodology is a conservative approach as regular monitoring of the wetland communities and their underlying hydrology is required before relationships can be confidently described (Eamus *et al*. 2006). This methodology is applied only to minimum and maximum water levels in wetlands and does not consider key aspects of the water regime including seasonality, duration and magnitude of change.

[4] Considers change in annual average minimum and maximum water levels only and does not consider key aspects of the water regime including seasonality, duration and magnitude of change.

3. The Murray region

3.1 Study area

The study area of the DWMP is shown in Figure 1. The study area encompasses an area of approximately 374 km^2 and extends between the Nambeelup Brook catchment in the north; Lower Serpentine River and Peel Inlet/Harvey Estuary in the west; Fauntleroy Drain catchment in the south and the Murray River and Darling Range foothills in the east.

The study area includes the localities of Keysbrook, North Dandalup, Nambeelup, Stake Hill, Barragup, Furnissdale, North Yunderup, Ravenswood, Fairbridge, Pinjarra, Meelon, Blythewood, West Pinjarra, Nirimba, South Yunderup and Dudley Park. Most of these localities are within the Shire of Murray; less than 10% of the study area is within the Shire of Serpentine-Jarrahdale.

3.2 Existing land use

Existing land use within the study area is predominately rural. Urban and urban deferred areas are mainly located around the townsites of Furnissdale, Yunderup, Ravenswoood, Pinjarra and North Dandalup. Regional open space areas exist in scattered locations along the Peel Harvey estuary and Murray and Serpentine rivers. Timber production is limited to the southern corner near Myalup. Industrial areas exist near Pinjarra and Stake Hill.

Rural land uses within the study area are predominantly of a broad acre agricultural nature. The majority is utilised for either beef cattle or dairy cattle. Other significant land uses include equestrian activities, mining and sheep farming. The Peel-Harvey estuary is used extensively for public recreation. Fishing is a major social value where it supports the largest estuarine fishery in WA.

Three major highways crossing the Peel region's boundaries and the extended Kwinana Freeway dissects the Study area. Some areas around Nambeelup/Keralup have been rezoned as a significant industrial area in the region.

The eastern shores of the Peel-Harvey Estuary are currently zoned for nature conservation, recreation, urban and high human population. There are a number of areas allocated for regional open space zoned for public purposes. There are a number of greenbelt rural living areas within these allocations.

The study area is rich in basic raw materials and contains areas that are identified by the Department of Industry and Resources as containing known mineralisation which should be set aside for future mining.

3.3 Topography, soils and geomorphology

The study area is contained within the Swan Coastal Plain geomorphic region. Elevations vary little within the majority of the study area but sharply increases to the east as the Darling Scarp is approached. There are also some localised elevated areas across the study area. Along the base of the Darling Scarp border the oldest exposed geological unit is the Yoganup Formation followed in order of age by the Guildford Formation, Bassendean Sand, Tamala Limestone, Tamala Sand and Safety Bay Sand. Concentrations of heavy mineral sands occur within the Yoganup Formation. The Guildford Formation consists of alluvial sands and clay.

The Swan Coastal Plain is dominated by three primary soil landscape zones, each with a number of component soil-landscape systems (progressing from west to east); Coastal, Bassendean and Pinjarra. The majority of the study area is classified as Bassendean or Pinjarra zone, with small areas of Coastal zone to the west.

The Perth Coastal Zone consists of beach ridges and parabolic dunes of calcareous deep sands nearest the coast, and areas of low dunes with yellow deep sands overlying Tamala limestone, inland to the east. The component soil-landscape systems are; Quindalup Dunes, Spearwood Dunes, and the Vasse Estuarine Deposits. Both the Quindalup and Spearwood dune systems are underlain by limestone. The Quindalup dunes are composed of unconsolidated sand (quartz grains) and shell fragments. They have a high leaching ability.

The Bassendean Zone consists of fixed dunes located inland from the coastal zone. It is a complex of low dunes, sand plains and swampy flats with pale deep sands and semi-wet and wet soils. Within the sub-regional structure plan area the Bassendean Zone comprises only one soil-landscape system of the same name. The soils are highly leached, infertile, and acidic and the low-lying areas are subject to inundation during winter. Under such conditions there is a high risk of nutrient export, an issue that has dominated environmental concerns with the coastal plain portion of the Catchment for some time.

The Pinjarra Zone covers the inland portion of the Swan Coastal Plain. The component soil-landscape systems include Pinjarra Plain and Forrestfield (the Ridge Hill Shelf). Much of the Pinjarra Plain has formed on the Guildford geological formation. It is a flat and generally poorly drained alluvial plain. Soils are a mix of grey deep sandy duplex soils, grey shallow sandy duplex soils, brown shallow loamy duplex soils and wet soils. The low permeability in some areas can lead to salt accumulation.

The predominant soils in the study area have a low (<5) phosphorus retention index, which may indicate a tendency to leach phosphorus by movement with water through and across the soil.

3.4 Surface water

The study area is traversed by the lower reaches of the Serpentine and Murray Rivers and bordered to the west by the Peel-Harvey Estuary. The Murray River, and its major tributaries the Hotham and Williams Rivers, is the largest of the catchments draining into the Peel-Harvey Estuary.

Flows in the Serpentine River are smaller than the Murray River due to its smaller catchment .The river discharges into the Peel Inlet just north of the Murray River's mouth and the two rivers form a broad delta.

There are a number of other smaller rivers and streams that flow into or through the study area, including: Nambeelup Brook; the Dandalup River system, incorporating the North and South Dandalup Rivers; Oakley and Marrinup Brooks; and a number of small streams that enter the flood study area from the east and drain into the Murray River (the Hills Catchments).

There are many small drains on farmland, particularly in and south of the Nambeelup Brook catchment. These have generally been constructed by landholders to drain wetlands and ponded areas.

3.5 Hydrogeology

There are three distinct aquifers underlying the study area, each being assigned the name of the major geological unit contributing to it. From natural surface level in increasing order of depth are:

- Superficial aquifer (unconfined);
- Leederville Aquifer (semi-confined); and
- Yarragadee (confined).

Many ecosystems and wetlands on the coastal plain are groundwater dependent and a number of rivers and creeks are also hydrologically linked to ground water systems. The wetlands within the Murray region are predominantly surface expressions of the superficial aquifer.

Groundwater resources in the study area are predominantly accessed for irrigation of pastures and horticultural crops, as well as mining, although they are also important as potential future fit-for-purpose water sources.

3.6 Environmental assets

3.6.1 Flora and fauna

Flora and fauna that may be present within the Murray DWMP study area were identified using the following databases:

- NatureMap database; and
- Department of the Environment, Water, Heritage and Arts (DEWHA) database for flora and fauna listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

DEC maintains the NatureMap database to provide maps, lists and reports of the biodiversity of Western Australia's flora and fauna.

The EPBC Act is the Australian Government's principal piece of environment legislation. The DEWHA maintains a database of matters of national environmental significance that are protected under the EPBC Act.

Rare and priority flora species and threatened fauna species that may be present in, or relate to, the Murray study area under the NatureMap and EPBC Act databases are provided in Appendix C.

3.6.2 Remnant vegetation and natural areas

About 85% of the native vegetation in the study area had already been cleared for agriculture and settlement, mostly on the Bassendean Dunes, Pinjarra Plain and along the river systems by 1997. In the last decade further clearing has occurred, especially for residential areas. Ten natural subdivisions occur in the study area based on landform and vegetation. The Pinjarra Plain forms just over half of the study area, is almost completely cleared due to its relatively fertile soils and has been extensively drained for agriculture.

Beyond the areas of strong saline influence, the vegetation of the Serpentine, Murray and Harvey Rivers is also predominantly cleared. Relatively intact areas are uncommon and provide reference sites for rehabilitation activities. The vegetated areas in the lower reaches of the Serpentine River are of particular significance as they are not typical of similar communities found elsewhere on the Swan Coastal Plain due to the presence of salt tolerant vegetation, unusual combinations of species and areas of ironstone.

3.6.3 Ramsar wetlands – international significance

Australia's internationally significant wetlands are listed under the Ramsar Convention. The Convention encourages the designation of wetland sites containing representative, rare or unique wetland types, or that are important for conserving biological diversity. The Peel Yalgorup system is the largest registered Ramsar site in the south-west, and consists of a large number of inter-connected wetlands, lakes, rivers, drainage features and groundwater aquifers that contribute to the complex hydrology of the area.

3.6.4 Important wetlands – national significance

Nationally important wetlands are considered to be significant to the Australian environment and are included in the *Directory of important wetlands in Australia*. Wetlands of national significance within the study area include the Peel-Harvey Estuary and Barragup Swamp.

3.6.5 Wetlands of regional significance

The Department of Environment and Conservation has evaluated and classified the majority of coastal plain wetlands of the Perth-Bunbury region. The purpose of this classification is to ensure an integrated approach to the management of catchments, and for managing water quantity and quality levels where they have the potential to affect environmental, cultural and other wetland values. The management category assigned to a wetland provides guidance on the management objectives for the wetland. Wetlands of the Swan Coastal Plain have been assigned wetland management categories as identified in Table 4 (Hill *et al*. 1996).

The classification system developed by the Semenuik Research Group was used to classify wetlands on the Swan Coastal Plain based on landform and water permanence (Hill *et al*. 1996) (Table 5).

The predominant wetlands found within the Murray region include:

- A large part of the floodplain within the Murray study area is mapped as Multiple Use palusplain wetland.
- The rivers within the Murray study area are predominantly mapped as linear (river) Conservation category wetlands.
- The Peel Inlet and Harvey Estuary and its periphery estuarine areas are predominantly mapped as Conservation category Estuary-Waterbody or Estuary-Peripheral type wetlands.
- Number of the lakes and sumplands are identified as Conservation category wetlands within the study area.

Table 4 Wetland management category

Management category	General description	Management objectives
Conservation	Wetland which support a high level of attributes and functions	Highest priority wetlands. Objective is to preserve and protect the existing conservation values of the wetlands through various mechanisms including: ◗ Reservation in national parks, crown reserves and State owned land, ◗ Protection under Environmental Protection Policies, and

Management category	General description	Management objectives
		◗ Wetland covenanting by landowners. No development or clearing is considered appropriate . These are the most valuable wetlands and any activity that may lead to further loss or degradation is inappropriate.
Resource enhancement	Wetlands which may have been partially modified but still support substantial ecological attributes and functions	Priority wetlands. Ultimate objective is to manage, restore and protect towards improving their conservation value. These wetlands have the potential to be restored to Conservation category. This can be achieved by restoring wetland function, structure and biodiversity. Protection is recommended through a number of mechanisms.
Multiple use	Wetlands with few remaining important attributes and functions	Use, development and management should be considered in the context of ecologically sustainable development and best practice catchment planning through landcare.

Table 5 Wetland classification system

Wetland type	General description
Basin wetlands	Dampland = seasonally waterlogged basin Sumpland = seasonally inundated basin Lake = permanently inundated basin Artificial basins (e.g. dams, reservoirs)
Flat wetlands	Floodplain = seasonally inundated flat Palusplain = seasonally waterlogged flat

3.6.6 Environmental protection policy wetlands

The Environmental protection (Swan coastal plain lakes) policy (1992) identifies specific wetlands on the coastal plain and provides them with statutory protection from disturbance. The policy prohibits the filling, mining, pollution or changing of drainage into or out of those wetlands without assessment and approval by the Environment Protection Authority. The Environmental protection policy lakes located within the study area are shown in Figure 6.

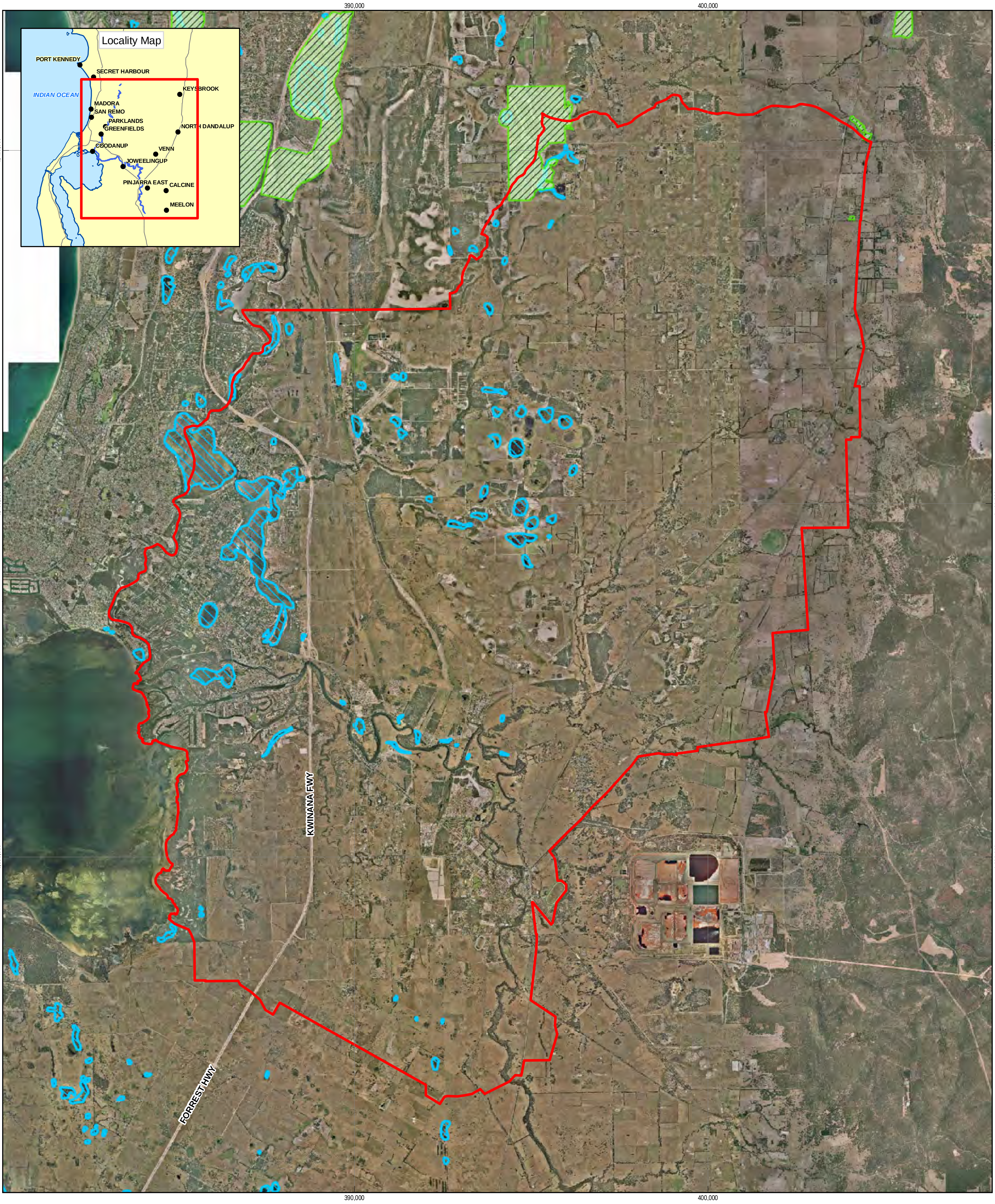
3.6.7 Bush Forever sites

The study area contains regionally significant bush subject to the Bush Forever policy along with threatened ecological communities and declared rare and priority flora. There is also a significant amount of scattered remnant vegetation throughout the study area.

Bush Forever identifies regionally significant bushland to be retained and protected forever. It is one of the most significant conservation initiatives ever undertaken in Western Australia. Following guidelines set by the World Conservation Union, Bush Forever aims to protect a target figure of at least 10 per cent of the 26 original vegetation complexes within the Swan Coastal Plain portion of metropolitan Perth, and to conserve threatened ecological communities.

Three Bush Forever sites are present within the study area (Figure 6). All occur within the locality of Keysbrook within the Shire of Serpentine-Jarrahdale:

- Site 77: Yangedi Swamp, Keysbrook;
- Site 78: Page Road Bushland, Keysbrook; and
- Site 426: Myara Brook Bushland, Keysbrook.



LEGEND

- Study Area
- Bush Forever 2007 - Sites
- EPP 1992 Lakes Register Boundaries - Swan Coastal Plain

1:100,000 (at A3)

0 0.5 1 2 3 4 5
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 50

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GHD
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Department of Water

Department of Water
Murray Drainage and Water Management Study

Job Number	61-2393704
Revision	A
Date	30 AUG 2010

EPP Lakes and Bush Forever Sites

Figure 6

G:\61\2393706\GIS\mxds\612393704-G009_Figure 6 - EPP Lakes and Bush Forever Sites - QAd.mxd

GHD House, 239 Adelaide Terrace Perth WA 6004 **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Data Source: DOW: Study Area - 20081202; Landgate (SLIP): Metro South 2009 Mosaic - SLIP 20090627; EPP: EPP 1992 Lakes Register Boundaries - Swan Coastal Plain - 20100608; DPI: Bush Forever 2007 Sites - 20100608. Created by: Nik Fadhil, xntan, kdiralu, jhchen

4. Wetland UFI 3945 (Barragup Swamp)

Wetland UFI 3945, colloquially known as Barragup Swamp, is a large wetland located south-west of Pinjarra Road, in the locality of Barragup. Barragup Swamp is categorised as a conservation category sumpland.

The wetland is surrounded by a largely semi-rural community (classified as Special Rural) with some low-level commercial development along Pinjarra Road. Barragup Swamp receives surface water drainage from the surrounding semi-rural community through a large drain in the south-west of the wetland as well as road runoff through a piped network. It is possible that the wetland may recharge groundwater at some times during the year due to surface water runoff into the wetland from the surrounding land.

4.1 Background data

4.1.1 Directory of important wetlands in Australia

Barragup Swamp is listed in the Directory of important wetlands in Australia, and is therefore a wetland of national importance. The wetland is recognised as a freshwater swamp forest on inorganic soils (May and McKenzie 2003).

4.1.2 EPP Lakes

Barragup Swamp is listed as an EPP Lake.

4.1.3 Previous studies

Bowman Bishaw Gorham completed a study of Barragup Swamp in 1989, updated in 1990. A summary of the key information relating to wetland ecological values and water regime is provided below.

Vegetation

BBG (1990) noted that the wetland vegetation rapidly changes from swamp vegetation to typical Banksia, Nutysia woodland outside the wetland area. Key wetland species included *Melaleuca rhaphiophylla* and *Melaleuca cuticularis*, *Chenopodium macrospermum*, *Suaeda Australia*, *Sarcocornia quinqueflora*, *Baumea juncea*, *Lepidosperma longitudinale*, *Banksia littoralis*, *Acacia saligna*, *Viminaria juncea*, *Eucalyptus rudis*.

Fauna

The swamp is valued as a refuge and breeding habitat for a diverse range of water birds, including the largest breeding colony of Yellow-billed Spoonbills in Western Australia (BBG 1989). Fauna survey data included a review of previous birdlife surveys.

Wetland hydrology

The wetland hydrology was described as surface expression of the shallow unconfined aquifer, with the water level within the wetland mimicking the seasonal cycle of rising and falling levels of the shallow groundwater system. There is a lag of up to two months in the post-winter decline of swamp water level.

Environmental processes

BBG (1990) observed that the hydrological cycle is the primary influence in the wetland's ecology and critical for maintaining food and habitat for fauna. Barragup Swamp was experiencing increasing water levels during the period, estimated to be at least 0.5m within the wetland and peripheral groundwater, and BBG noted that if the extent and duration of the seasonal flooding were to increase the habitat value of the swamp would reduce.

4.2 Site specific ecological data

The locations of the ecological survey sites for Barragup Swamp are shown in Figure 7.

4.2.1 Vegetation and flora survey

The vegetation community types surveyed along the vegetation transect are described in Table 6. The native vegetation condition ranged between Very Good (4) to Completely Degraded (6). Most of the surveyed area within the wetland has been cleared in the past and severe weed invasion is present. Rubbish and fencing were also present in these areas.

Table 6 Vegetation community types for Barragup Swamp

Vegetation community name	Vegetation community description[1]	Elevation range (mAHD)	Rare and priority species
*Ec *Rr	Closed grassland of **Ehrharta calycina, *Romulea rosea, Bromus diandrus* and weed spp	1.70-1.70	
Eg Mi	Open forest of *Eucalyptus gomphocephala* over tall shrubland of *Melaleuca incana* subsp *incana* over closed grassland of **Bromus diandrus*	1.30-1.70	
Mr *Psp	Open forest of *Melaleuca rhaphiophylla* over sedgeland, grassland of **Polypogon* sp. and scattered herbs of **Cotula coronopifolia*	0.75-1.30	
Mr *Cd	Low open forest of *Melaleuca rhaphiophylla* over grassland of **Cynodon dactylon*	0.50-0.75	
OW	Open water	0.00-0.50	
Mp	Low woodland of *Melaleuca rhaphiophylla*, *Melaleuca incana* subsp *incana*. and planted tree spp. over mowed grassland of weed spp.	1.45-2.70	

4.2.2 Native fish and amphibian survey

No native fish species were recorded. Two frog species were recorded during the site specific survey including one identified by its call (*Crinia insignifera*) and *Heleioporus eyrei* which was observed at the site (not calling).

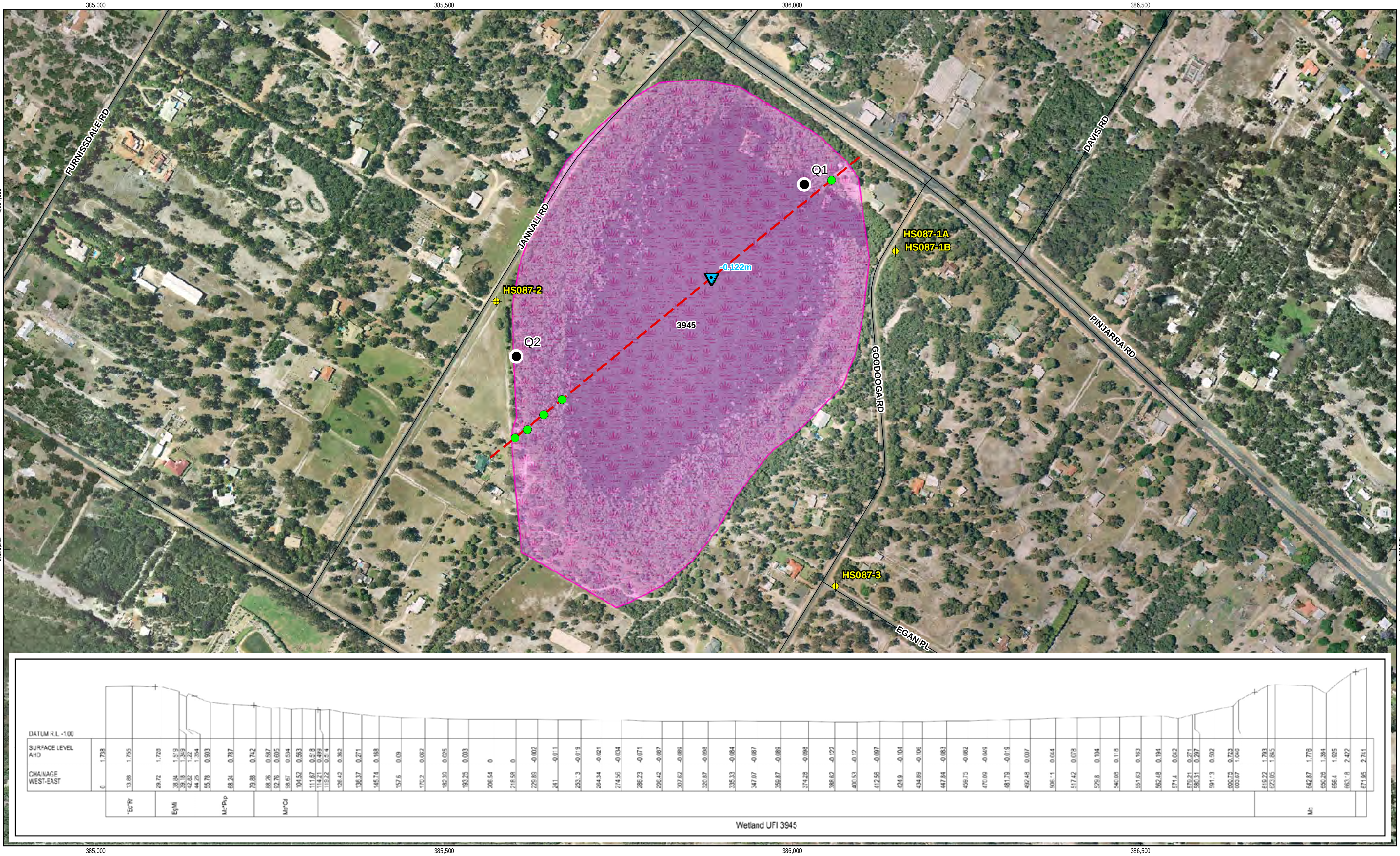
[1] * Denotes introduced species

4.3 Ecological values and environmental objectives of Barragup Swamp

The ecological values, conceptual environmental management objectives and operational (measurable) environmental management objectives are based on the desktop assessment and site specific ecological surveys (Table 7). The operational environmental objectives for the wetland are determined for the vegetative components of the wetland due to the relatively transient nature of faunal populations and the difficulties associated with monitoring other ecosystem processes such as sediment processes. The established vegetation transect will enable future monitoring to determine if the operational environmental management objectives are being met.

Table 7 Ecological values and environmental objectives of Barragup Swamp

Conservation significance	Ecological value	Site specific values	Environmental objective	Operational environmental management objective
State CCW DRF EPP Lake *Federal* EPBC Act *Directory of important wetlands in Australia*	Wetland retains high ecological values Vegetation may contain conservation significant flora including rare and priority flora species Wetland ecosystem may contain habitat that supports significant fauna including threatened fauna and migratory bird species protected under the JAMBA and CAMBA agreements	Vegetation condition *Very Good* to *Completely Degraded*	To maintain biodiversity To maintain hydrological functions Protect the habitat of significant fauna	To maintain species composition To maintain species distribution To maintain species richness To control species mortality To maintain species condition and vigour To maintain community structure



1:5,000 (at A3)

0 25 50 100 150 200 250

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 50

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LEGEND

- Vegetation Type Boundaries
- Frog and Fish Assessment Points
- Borehole
- mAHD Lowest Surveyed Point
- Approximate Transect Line
- Roads

Geomorphic Wetlands

- Conservation
- Resource Enhancement
- Multiple Use
- Not Assessed
- Not Applicable

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Wetland UFI 3945
Barragup Swamp

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Figure 7

G:\61\2393706\GIS\mxds\612393704-G004_Figure 7 - Wetland UFI 3945 Barragup Swamp - QAd.mxd

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Data Source: DEC: Geomorphic Wetlands, Swan Coastal Plain - 20070319; GHD: Approximate Transect Lines - 20090624; Landgate: Metro South 2009 Mosaic - 20090627; Landgate: Roads - 20090625; GHD: Murray Wetland Boreholes - 20100119, Lowest Surveyed Points - 20100330; GHD: Frog and Fish Assessment Points - 20090821. Created by: kdiralu, jhchen

4.4 Description of water regime

4.4.1 Surface water

Surface water levels within Barragup Swamp display distinct seasonal fluctuations in response to climatic conditions (Figure 8).

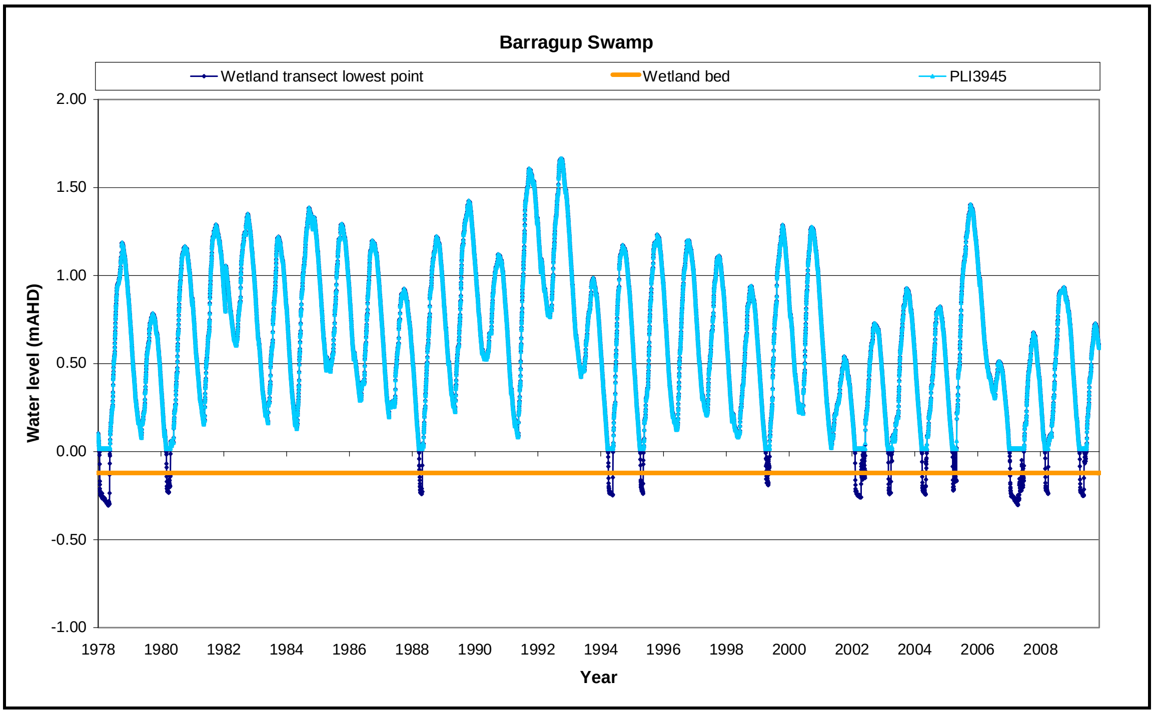


Figure 8 Modelled surface and ground water level in Barragup Swamp at the lowest point along the wetland transect and PLI

The minimum surface water level in Barragup Swamp along the ecological survey transect is -0.12 mAHD, corresponding with the lowest surveyed elevation point. The modelled absolute and annual average minimum and maximum surface water levels for various time periods are displayed in Table 8.

Table 8 Barragup Swamp modelled absolute and annual average minimum and maximum surface water level[1]

Period	Minimum		Maximum	
	mAHD	mAGL	mAHD	mAGL
1978-2009 (absolute)	-0.12	0	1.66	1.78
20 year annual average	0.13	0.25	1.10	1.22
10 year annual average	0.04	0.16	0.94	1.06

[1] mAGL is taken for the lowest point along the wetland transect

Period	Minimum		Maximum	
	mAHD	mAGL	mAHD	mAGL
5 year annual average	0.02	0.14	0.96	1.08
Timing	March-May		September-October, January	

4.4.2 Groundwater

Three groundwater monitoring bores were established around Barragup Swamp (Figure 7). Groundwater monitoring bore HS087-1 is located along the eastern boundary of the wetland, bore HS087-2 is located along the western boundary and HS087-3 is located to the south-east of the wetland. The minimum and maximum groundwater levels and the general timing that these occur are outlined in Table 9. The groundwater levels in the monitoring bores that surround Barragup Swamp show similar distinct seasonal fluctuations in response to climatic conditions.

Table 9 Barragup Swamp modelled absolute and annual average minimum and maximum groundwater level

	HS087-1		HS087-2		HS087-3	
Minimum	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL
1978-2009 (absolute)	-0.40	2.77	-0.27	1.66	-0.3	2.44
20 year annual average	-0.09	2.46	0.10	1.29	-0.01	2.15
10 year annual average	-0.22	2.59	0.01	1.38	-0.10	2.24
5 year annual average	-0.25	2.62	-0.01	1.40	-0.10	2.24
Timing	March-May		March-May		March-May	
Maximum	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL
1978-2009 (absolute)	2.00	0.37	1.67	-0.28	2.08	0.06
20 year annual average	1.38	0.99	1.28	0.11	1.67	0.47
10 year annual average	1.20	1.17	1.18	0.21	1.47	0.67
5 year annual average	1.22	1.15	1.20	0.19	1.45	0.69
Timing	August-October		August-October		July-September	

4.4.3 Annual period of drying

Surface water data show that Barragup Swamp was inundated for extended periods in the years 1979-1992 (dry in 1980 and 1987) and 1996-2001 (dry in 1999). Since 2002 the swamp has dried every summer. The modelled water level record was assessed to identify the annual period of drying, with summary statistics provided in Table 10. The summary statistics show that Barragup Lake doesn't dry in all years, and has a historical maximum period of drying of 135 consecutive days in 2007 (approximately 4.5 months). For the whole period 1978-2009 the swamp has historically dried for approximately one month in 70% of years. For the period 2000-2009 Barragup Swamp dried for approximately one month in 50% of years.

Table 10 Barragup Swamp modelled annual drying statistics

Annual drying statistics	1978-2009 (days)	2000-2009 (days)
Minimum	0	0
10th percentile	0	0
30th percentile	0	10
50th percentile	0	31
70th percentile	30	45
90th percentile	52	75
Maximum	135	135

4.4.4 Water level magnitude of change

The modelled magnitude of change (increase and decrease) in minimum and maximum water level for Barragup Swamp is displayed in Table 11. Minimum water levels experienced larger increases and decreases in water levels between years than maximum water levels. For minimum water levels the rate of change is similar for both the peak increase and decrease in water levels, whereas for maximum water levels the increase in water levels between years is higher than the peak decline between years.

Table 11 Barragup Swamp modelled magnitude of change in annual minimum and maximum water levels

	Minimum levels	Maximum levels
Maximum increase (m/year)	0.68 (1991-1992)	0.58 (2004-2005)
Maximum decrease (m/year)	-0.67 (1993-1994)	-0.49 (2000-2001)

4.4.5 Water quality

4.4.5.1 Physiochemical parameters

TDS in Barragup Swamp ranged from between 7,836 mg/L (October 2009) and 13,604 mg/L (December 2009). The pH ranged between 9.18 (August 2009) and 9.60 (September 2009).

4.4.5.2 Nutrients

Total nitrogen and total phosphorus samples were collected and analysed for a single snapshot monitoring event in September 2009. Concentrations were reported as 2.3 mg/L for TN and 0.046 mg/L for TP.

4.5 Water requirement to maintain vegetation communities

The water requirements for selected vegetation communities at Barragup Swamp are summarised below. Figures displaying the water requirements of vulnerable species as well as the existing water levels at the upper and lower elevation extent of the vegetation communities are located in Appendix D.

4.5.1 Vegetation community Mr

To maintain the most vulnerable species for vegetation community Mr (*Melaleuca rhaphiophylla*) at a low level of risk a range in groundwater level of between -0.67 and 2.77 mAHD may be required based on the mean SW water level range for this species. Modelled minimum groundwater levels typically range between -0.25 and 0.25 mAHD for both the lower and upper elevation extents of the vegetation community which are above the mean minimum SW water level (Most vulnerable L min) for the lower elevation extent and should therefore meet the requirements of the most vulnerable species at the lower elevation. For the upper elevation extent the minimum water levels are between the mean minimum SW water level (Most vulnerable U min) and the absolute SW minimum value (Most vulnerable U min ABS).

4.5.2 Vegetation community Mr*Psp

To maintain the most vulnerable species for vegetation community Mr*Psp (*Melaleuca rhaphiophylla*) at a low level of risk a range in groundwater level of between -1.37 and 1.37 mAHD may be required based on the mean SW water level range for this species. Modelled minimum groundwater levels are generally above -0.30 mAHD and should therefore meet the requirements of the most vulnerable species. Modelled maximum groundwater levels generally fall between the mean maximum SW water level at the upper elevation extent (Most vulnerable U max) and the mean maximum SW water level at the lower elevation extent (Most vulnerable L max).

Based on the modelled water level data the vegetation community is regularly inundated at its lower elevation of 0.75 mAHD, however is only occasionally inundated at its upper elevation extent of 1.3 mAHD.

4.6 Interim ecological water requirements to maintain the environmental objectives

The EWRs to maintain the environmental objectives of Barragup Swamp are summarised in

Table 12. The EWRs are of an interim nature and are based on the modelled wetland water regime. Comparison of the maximum and minimum water level values, the range in values and the timing of peak surface water values identify that the interim EWRs are able to meet the water requirements of the vegetation communities as described in Section 4.5. It is assumed that maintenance of the water regime of the vegetation communities will ensure other ecological objectives of the wetland.

Table 12 Interim ecological water requirements for Barragup Swamp

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	Interim EWR	Limits of acceptable change
Maintain biodiversity	Condition: Vegetation condition *Very Good to Completely Degraded* Trend: Trend in vegetation condition not identified as only single survey conducted	**Groundwater level**			
		Maximum	HS087-1: 0.87 to 2.00 mAHD (1.20 mAHD) HS087-2: 0.84 to 1.67 mAHD (1.18 mAHD) HS087-3: 0.95 to 2.08 mAHD (1.47 mAHD)	Timing: peak water levels generally between July and October	Limit unable to be set due to limited site specific data
		Minimum	HS087-1: -0.39 to 0.63 mAHD (-0.22 mAHD) HS087-2: -0.27 to 0.70 mAHD (0.01 mAHD) HS087-3: -0.37 to 0.61 mAHD (-0.10 mAHD)	Timing: minimum water levels generally between March and May	
		Surface water level			
		Maximum	0.67 to 1.66 mAHD (0.94 mAHD) Maximum water level > 1.25 mAHD: 2 in 10 years	>1.25 mAHD in 2 out of 10 years Timing: peak water levels generally occur in September to October, or January	Limit unable to be set due to limited site specific data
		Minimum	1978-2009: -0.122 to 0.76 mAHD (0.04 mAHD)	Not > -0.122 mAHD > 7 consecutive years Timing: minimum water levels generally between March and May	
		Period of drying			
		Median	1978-2009: 0 days 2000-2009 (drying phase): 31 days	Permanent water present for no more than 7 consecutive years (i.e. not > -0.122 mAHD)	Limit unable to be set due to limited site specific data
		Maximum	135 consecutive days		

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	Interim EWR	Limits of acceptable change
		Magnitude of change in water level			
		Maximum	Increase: 0.58 m/yr Decrease: 0.49 m/yr	Magnitude of change should not exceed historic levels.	
		Minimum	Increase: 0.68 m/yr Decrease: 0.67 m/yr	Peak levels should not occur in successive years. Water levels should not remain stable i.e. 0 m/yr magnitude of change in successive years.	Limit unable to be set due to limited site specific data

4.7 Scenario assessment for Barragup Swamp

4.7.1 Hydrologic zone analysis (EWR_S2, EWR_S3 and EWR_S4)

The hydrologic zone analysis identified that in order to achieve a change in average wetland water level of less than 10% a minimum hydrologic zone extent of at least 600 m is required for drainage at 1 m below ground level, an extent of approximately 350 m is required for drainage at 0.5 m below ground level and an extent of 200 m is sufficient for drainage at AAMaxGL.

4.7.2 Climate scenarios (EWR_S5, EWR_S7 and EWR_S8)

The effect of climate change on the minimum and maximum water level depth for Barragup Swamp is displayed in Table 13.

4.7.2.1 Minimum water levels

The assessment of climate change scenarios on minimum water levels identified that all of the scenarios result in greater than 10% change in average annual minimum groundwater levels. The predicted change in minimum water levels ranges between 13% for the wet climate scenario (EWR_S5) and 187% for the historical wet climate scenario (EWR_S8). The dry climate scenario (EWR_S7) predicts a decline of 126%.

4.7.2.2 Maximum water levels

The wet climate scenario (EWR_S5) predicts a 2% increase in average annual maximum water level, abd the historical wet climate scenario predicts a 31% increase compared to the base case scenario. The predicted change for the dry climate scenario was a 29% decline (0.36 m decline compared to base case).

Table 13 Change in Barragup Swamp wetland water levels for wet, dry and historical wet climate change scenarios

Change in groundwater level compared to base case (S0)	S5		S7		S8	
	m	% change	m	% change	m	% change
AAMinGL	0.02	13%	-0.24	126%	0.35	187%
AAMaxGL	0.03	2%	-0.36	29%	0.38	31%

4.7.3 Sea level change scenario (EWR_S9)

The effect of climate change on the minimum and maximum water level depth for Barragup Swamp is displayed in Table 14.

4.7.3.1 Minimum water levels

The assessment of the sea level change scenarios on minimum water levels predicts an increase in average annual minimum groundwater levels of 0.26 m or 136%.

4.7.3.2 Maximum water levels

The sea level change scenario predicts an 18% (0.23 m) increase in average annual maximum water level.

Table 14 Change in Barragup Swamp wetland water levels for sea level change scenario

Change in groundwater level compared to base case (S0)	S9	
	m	% change
AAMinGL	0.26	136%
AAMaxGL	0.23	18%

4.8 Risk of impact mapping

The risk of impact mapping for Barragup Swamp is displayed in Figure 9. The mapping displays high risk of impact for the AAminGL for scenarios S7, S8 and S9 at the vegetation change locations, and for AAminGL for scenario S9. Moderate to high risk of impact is mapped for the AAminGL for scenario S5, and for AAmaxGL for scenarios S7 and S8.

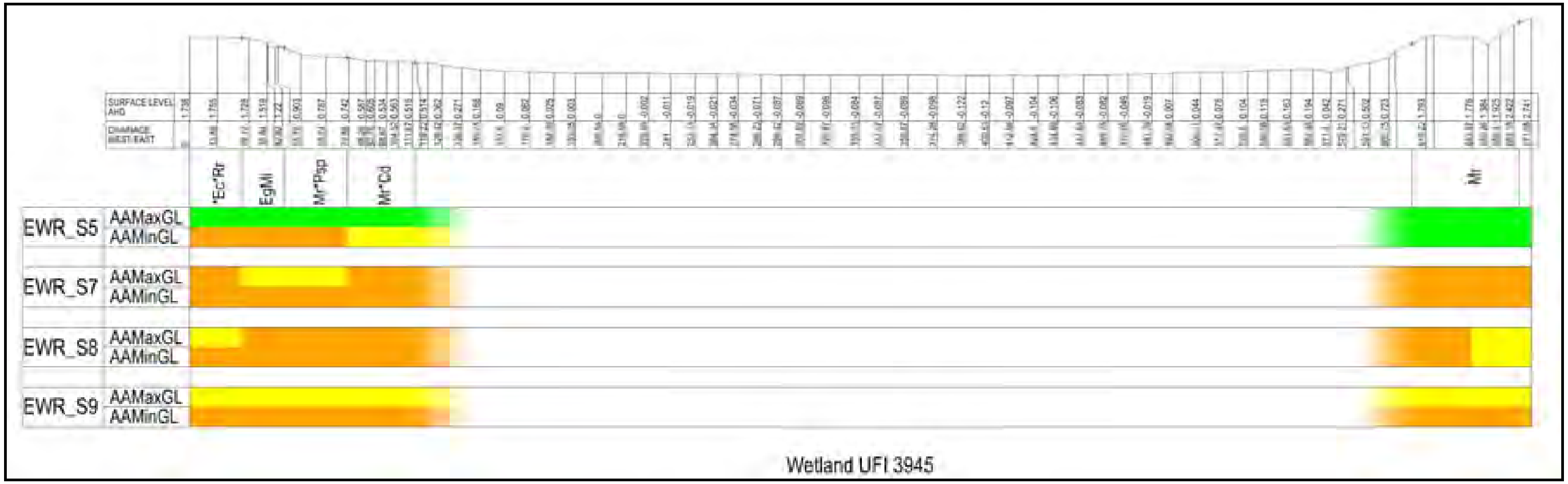


Figure 9 Barragup Swamp risk of impact mapping for climate change scenarios

5. Wetland UFI 5724 (Benden Road)

Benden Road Wetland (wetland UFI 5724 in the DEC Geomorphic Wetland Swan Coastal Plain dataset) is located approximately 1.2 km north east of Scott Road Wetland (Figure 10). The wetland is a large circular wetland that is categorised as a conservation category sumpland. The wetland does not appear to receive water from surface water drains, nor does it discharge water to adjacent drains. It is seasonally inundated, and dry in late summer and early autumn.

5.1 Background data

5.1.1 EPP Lakes

Wetland UFI 5724 is listed as an EPP Lake.

5.1.2 Previous studies

Bowman Bishaw Gorham (2006) interpolated ground water levels within the Nambeelup area based on observed water levels in 20 monitoring bores. Within the vicinity of the Benden Road wetland the ground water level was interpolated as approximately 13.5 mAHD in June 2006, which suggests that the wetland is a surface expression of the superficial aquifer in winter months.

5.2 Site specific ecological data

The location of the ecological survey sites for Benden Road wetland are shown in Figure 10.

5.2.1 Vegetation and flora survey

The vegetation community types surveyed along the vegetation transect are described in Table 15. The native vegetation condition ranged between Excellent (2) to Completely Degraded (6). Most of the wetland rated Excellent (2) to Very Good (3). Weeds were present throughout the wetland and some clearing of native vegetation was evident. A small amount of rubbish was present in the wetland.

Table 15 Vegetation community types for Benden Road wetland

Vegetation community name	Vegetation community description	Elevation range (mAHD)	Rare and priority species
Em Ba	Low open forest of *Eucalyptus marginata* and *Banksia attenuata* over tall open scrub of *Melaleuca incana* subsp *incana* over sedgeland and grassland	15.50 -15.60	*Stylidium striatum* (P4)
Mp Kg	Open forest of *Melaleuca preissiana* over open shrubland of *Kunzea glabrescens* over open sedgeland with *Baumea articulata* and *Baumea pressii*	15.30 -15.50	
Mp Kg Ba	Low open forest of *Melaleuca preissiana* over tall open scrub of *Kunzea glabrescens* over open sedgeland with *Baumea articulata* and *Baumea pressii*	13.50 -15.30	
Mp Cp	Closed tall scrub of *Melaleuca preissiana* over herbland	14.50 – 13.40	

Vegetation community name	Vegetation community description	Elevation range (mAHD)	Rare and priority species
	of *Cassytha* sp. over isolated sedges		
Bm Ba	Low open woodland of *Banksia menziesii, Banksia attenuata* and *Eucalyptus marginata* over tall open shrubland of *Kunzea ericifolia* over grassland	14.50 -15.50	

5.2.2 Native fish and amphibian survey

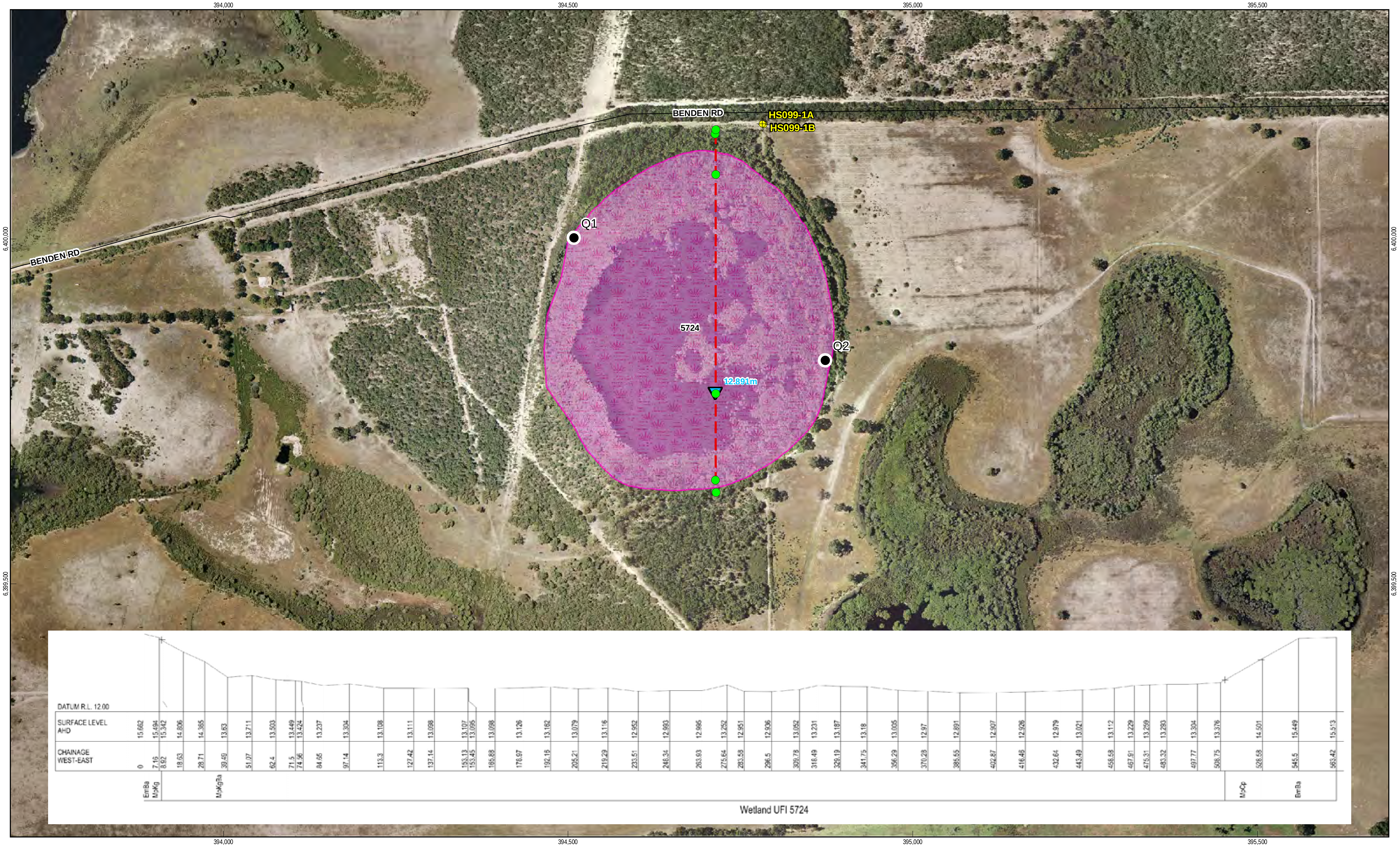
No native fish species were recorded. Seven frog species were recorded during the site specific survey including six species identified by their calls (*Litoria adelaidensis, Crinia glauerti, C. insignifera, C. georgiana, Lymnodynastes dorsalis and Pseudophyne guentheri*). One species was recorded as active and not calling (*Heleioporus eyrei).*

5.3 Ecological values and environmental objectives

The ecological values, conceptual environmental management objectives and operational (measurable) environmental management objectives are based on the desktop assessment and site specific ecological surveys (Table 16). The operational environmental objectives for the wetland are determined for the vegetative components of the wetland due to the relatively transient nature of faunal populations and the difficulties associated with monitoring other ecosystem processes such as sediment processes. The established vegetation transect will enable future monitoring to determine if the operational environmental management objectives are being met.

Table 16 Ecological values and environmental objectives of Benden Road wetland

Conservation significance	Ecological value	Site specific values	Environmental objective	Operational environmental management objective
State CCW DRF EPP Lake *Federal* EPBC Act	Wetland retains high ecological values Vegetation may contain conservation significant flora including rare and priority flora species Wetland ecosystem may contain habitat that supports significant fauna including threatened fauna and migratory bird species protected under the JAMBA and CAMBA agreements	Vegetation condition *Excellent* to *Completely Degraded* Priority species: ◗ *Stylidium striatum* (P4)	To maintain biodiversity To maintain hydrological functions Protect the habitat of significant fauna	To maintain species composition To maintain species distribution To maintain species richness To control species mortality To maintain species condition and vigour To maintain community structure



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0 25 50 100 150 200 250

Metres

Map Projection: Transverse Mercator
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N

LEGEND

- Vegetation Type Boundary
- Frog and Fish Assessment Points
- Borehole
- mAHD Lowest Surveyed Point
- Approximate Transect Line
- Roads

Geomorphic Wetlands

- Conservation
- Resource Enhancement
- Multiple Use
- Not Assessed
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Benden Road Wetland

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Figure 10

G:\61\2393706\GIS\mxds\612393704-G010_Figure 10 - Wetland UFI 5724 Benden Road Wetland - QAd.mxd

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5.4 Description of water regime

5.4.1 Surface water

The surface water level within Benden Road wetland displays distinct seasonal fluctuations in response to climatic conditions (Figure 11).

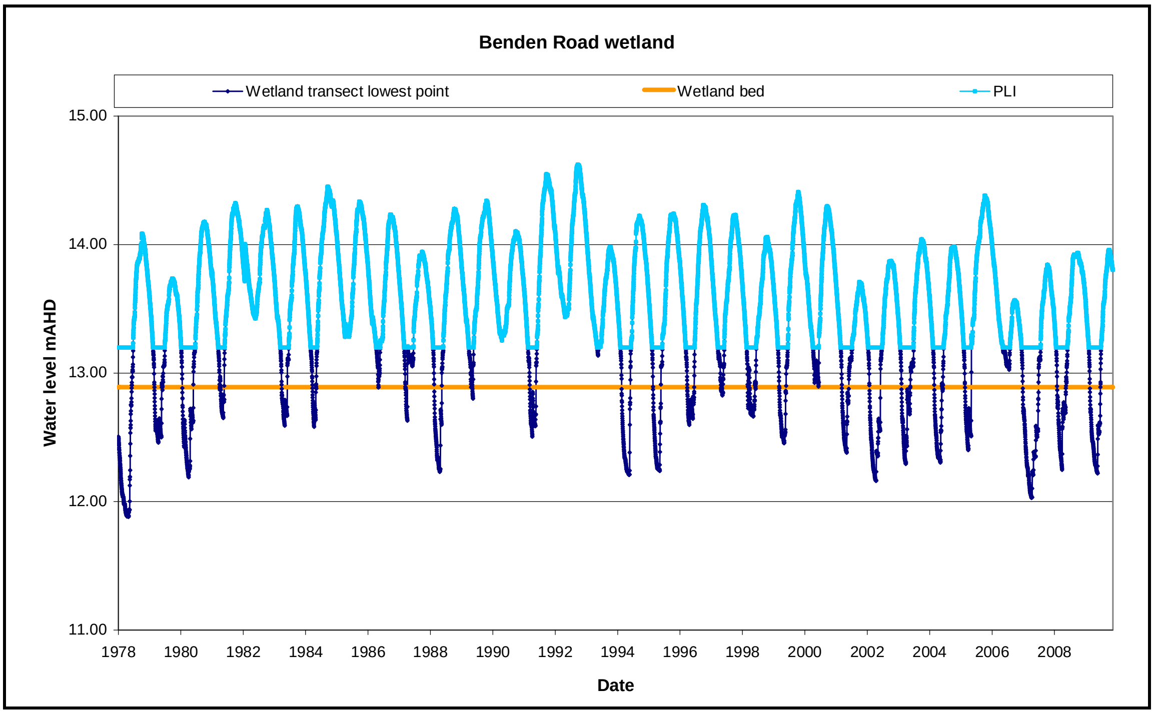


Figure 11 Modelled surface and ground water level in Benden Road wetland at the lowest point along the wetland transect and the PLI

The minimum surface water level in Benden Road wetland is 12.89 mAHD, corresponding with the lowest surveyed elevation point along the wetland transect. The minimum and maximum surface water levels for the various periods are displayed in Table 17.

Table 17 Benden Road wetland modelled absolute and annual average minimum and maximum surface water level

Period	Minimum		Maximum	
	mAHD	mAGL	mAHD	mAGL
1978-2009	12.89	0.00	14.62	1.73
20 year annual average	12.94	0.05	14.14	1.25
10 year annual average	12.90	0.01	14.00	1.11
5 year annual average	12.92	0.03	14.02	1.13

	Minimum	Maximum
Timing	March-May	September-October

5.4.2 Groundwater

Two nested groundwater monitoring bores were established at Benden Road wetland (Figure 10). Groundwater monitoring bores HS099-1A and HS099-1B are located to the north-east of the wetland. The minimum and maximum groundwater levels and the general timing that these occur are outlined in Table 18. The minor difference in the head levels between the nested bores, indicates that the wetland is not likely to be located on a perched aquifer.

Table 18 Benden Road wetland modelled absolute and annual average minimum and maximum groundwater level

	HS099-1A		HS099-1B	
Minimum	mAHD	mBGL	mAHD	mBGL
1978-2009	12.49	3.55	12.49	3.55
20 year annual average	12.99	3.05	13.00	3.04
10 year annual average	12.88	3.16	12.89	3.15
5 year annual average	12.86	3.18	12.87	3.17
Timing	March-May		March-May	
Maximum	mAHD	mBGL	mAHD	mBGL
1978-2009	14.87	1.17	14.87	1.17
20 year annual average	14.45	1.59	14.45	1.59
10 year annual average	14.34	1.70	14.33	1.71
5 year annual average	14.33	1.71	14.32	1.72
Timing	July-September		July-September	

5.4.3 Annual period of drying

Surface water data show that Benden Road wetland generally dries out. For the period 1978-2009 the lake appears to dry two or three times in a ten year period. The wetland remained inundated in the following years: 1982, 1985, 1990, 1992, 1993 and 2006. In the years 1986 and 2000 the groundwater level was at or just below the lake bed and some ponding of water may have occurred.

The modelled water level record was assessed to identify the annual period of drying, with summary statistics provided in Table 19. The summary statistics show that Benden Road wetland doesn't dry in all years, and has a historical maximum period of drying of 185 consecutive days in 2007 (approximately 6 months). When the whole period 1978-2009 is considered the wetland historically dries for over 2 months in 50% of years. For the period 2000-2009 Benden Road wetland dried for approximately three months in 50% of years.

Table 19 Benden Road wetland annual drying statistics

Annual drying statistics	1978-2009 (days)	2000-2009 (days)
Minimum	0	0
10th percentile	0	0
30th percentile	24	79
50th percentile	73	95
70th percentile	88	109
90th percentile	128	135
Maximum	185	185

5.4.4 Water level magnitude of change

The modelled magnitude of change (increase and decrease) in minimum and maximum water level for Benden Road wetland is displayed in Table 20. Minimum water levels experienced larger increases and decreases in water levels between years than maximum water levels. For minimum water levels the rate of change is equal for both the peak increase and decrease in water levels, whereas for maximum water levels the increase in water levels between years is higher than the peak decline between years.

Table 20 Benden Road wetland magnitude of change in annual minimum and maximum water levels

	Minimum levels	Maximum levels
Maximum increase (m/year)	0.93 (1991-1992)	0.44 (1990-1991)
Maximum decrease (m/year)	-0.93 (1993-1994)	-0.59 (2000-2001)

5.4.5 Water quality

5.4.5.1 Physiochemical parameters

TDS in Benden Road wetland ranged from between 1,053 mg/L (September 2009) and 1,420 mg/L (December 2009). The pH ranged between 5.80 (September 2009) and 6.11 (August 2009).

5.4.5.2 Nutrients

Total nitrogen and total phosphorus samples were collected and analysed for a single snapshot monitoring event in September 2009. Concentrations were reported as 4.9 mg/L for TN and 0.23 mg/L for TP.

5.5 Water requirement to maintain vegetation communities

The water requirements for selected vegetation communities at Benden Road wetland are summarised below. Figures displaying the water levels at the upper and lower extent of the vegetation communities for Benden Road wetland are located in Appendix D.

5.5.1 Vegetation community MpKgBa

To maintain the most vulnerable species for vegetation community MpKgBa (*Baumea articulata*) at a low level of risk a range in groundwater levels of between 12.30 and 15.60 mAHD may be required based on the mean SW water level range for this species. Modelled groundwater levels typically range between 12.50 and 14.30 mAHD at the lower elevation extent and 12.60 and 14.50 mAHD at the upper elevation extent. Modelled water levels are below the mean minimum SW water level at the upper elevation extent (Most vulnerable U min), however are very similar to the absolute SW minimum (Most vulnerable U min ABS).

Based on the modelled water level data the vegetation community is regularly inundated at its lower elevation of 13.5 mAHD, however is not inundated at its upper elevation of 15.3 mAHD.

5.5.2 Vegetation community MpCp

To maintain the most vulnerable species for vegetation community MpCp (*Juncus pallidus*) at a low level of risk a range in groundwater level of between 13.02 and 14.95 mAHD may be required based on the mean SW water level range for this species. Modelled minimum groundwater levels typically range between 12.15 and 12.90 mAHD, which is between the mean minimum SW water level (Most vulnerable L min) and the absolute SW minimum value (Most vulnerable L min ABS) for the lower elevation extent. The modelled water levels should therefore meet the requirements of the most vulnerable species at the lower elevation extent of this vegetation community.

Based on the modelled water level data the vegetation community is regularly inundated at its lower elevation of 13.4 mAHD, however is not inundated at its upper elevation of 14.5 mAHD.

5.5.3 Vegetation community BmBa

To maintain the most vulnerable species for vegetation community BmBa (*Baumea articulata*) at a low level of risk a range in groundwater level of between 13.30 and 15.20 mAHD may be required based on the mean SW water level range for this species. Modelled minimum groundwater levels typically range between 12.05 and 12.95 mAHD, which is between the mean minimum SW water level (Most vulnerable L min) and the absolute SW minimum value (Most vulnerable L min ABS) for the lower elevation extent. The modelled water levels should therefore meet the requirements of the most vulnerable species at the lower elevation extent of this vegetation community.

Based on the modelled water level data this vegetation community is rarely inundated at its lower elevation of 14.5 mAHD, and is not inundated at its upper elevation extent.

5.6 Interim ecological water requirements to maintain the environmental objectives

The EWRs to maintain the environmental objectives of Benden Road wetland are summarised in Table 21. The EWRs are of an interim nature and are based on the modelled wetland water regime. Comparison of the maximum and minimum water level values, the range in values and the timing of peak surface water values identify that the interim EWRs are able to meet the water requirements of the vegetation communities as described in Section 5.5. It is assumed that maintenance of the water regime of the vegetation communities will ensure other ecological objectives of the wetland.

Table 21 Interim ecological water requirements for Benden Road wetland

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	Interim EWR	Limits of acceptable change
Maintain biodiversity of Benden Road wetland (Wetland UFI 5724)	Condition: Vegetation condition ranged from *Excellent* to *Completely Degraded*. Majority of wetland vegetation rated *Excellent* to *Good*. Trend: Trend in vegetation condition not identified as only single survey conducted.	Groundwater level			
		Maximum	HS099-1A: 14.11 to 14.87 mAHD (14.34 mAHD) HS099-1B: 14.10 to 14.87 mAHD (14.33 mAHD)	Timing: peak water levels generally between July and September	Limit unable to be set due to limited site specific data
		Minimum	HS099-1A: 12.49 to 13.56 mAHD (12.88 mAHD) HS099-1B: 12.49 to 13.57 mAHD (12.88 mAHD)	Timing: minimum water levels generally between March and May	
		Surface water level			
		Maximum	13.71 to 14.62 mAHD (14.00 mAHD) Maximum water level > 14.30 mAHD: 2 in 10 years	>14.30 mAHD in 2 out of 10 years Timing: peak water levels generally occur in September to October	Limit unable to be set due to limited site specific data
		Minimum	1978-2009: 12.891 to 13.43 mAHD (12.90 mAHD) *Note PLI set at 13.20 mAHD*	Timing: minimum water levels generally between March and May	
		Period of drying			
		Median	1978-2009: 73 days 2000-: 95 days	Permanent water present for no more than 2 consecutive years	Limit unable to be set due to limited site specific data
		Maximum	185 consecutive days		
		Magnitude of change in water levels			
		Maximum	Increase: 0.44 m/yr Decrease: 0.59 m/yr	Magnitude of change should not exceed historic levels. Peak levels should not occur in successive years. Water levels should not remain stable i.e.	Limit unable to be set due to limited site specific data
		Minimum	Increase: 0.93 m/yr Decrease: 0.93 m/yr		

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	Interim EWR	Limits of acceptable change
				0 m/yr magnitude of change in successive years.	

5.7 Scenario assessment for Benden Road wetland

5.7.1 Sand dune analysis (EWR_S1)

The Benden Road wetland has significant dunes (up to 4 m high) to the north. The DoW WSB analysis of the change to wetland water regime based on the removal of the sand dunes identified a change to the average annual maximum wetland water level of 0.04 m corresponding to a 3.1% reduction in average maximum water level (Hall *et al*. 2010c).

5.7.2 Hydrologic zone analysis (EWR_S2, EWR_S3 and EWR_S4)

The hydrologic zone analysis identified that in order to achieve a change in average wetland water level of less than 10% a minimum hydrologic zone extent of at least 200 m is required. Reduction in average maximum water depth of approximately 12% could be achieved with drainage at AAMaxGL and a hydrologic zone extent of 100m for this wetland system.

5.7.3 Climate scenarios (EWR_S5, EWR_S7 and EWR_S8)

The effect of climate change on the minimum and maximum water level depth for Benden Road wetland is displayed in

Table 22.

5.7.3.1 Minimum water levels

The assessment of climate change scenarios on minimum water levels identified that none of the scenarios achieves a change in average annual minimum groundwater levels below 10%. The wet climate (EWR_S5) predicts a 40% decline while the historical wet climate (EWR_S8) scenario predicts a 66% increase in average annual minimum water level compared to base case. For the dry climate scenario (EWR_S7) the predicted change is a decline of over 0.60 m, exceeding 200% change from base case.

5.7.3.2 Maximum water levels

The wet climate scenario (EWR_S5) predicts change in the average annual maximum water levels of only 4%. For the dry climate (EWR_S7) the predicted change in maximum water level is 42%, a decline of over 0.50 m. The historical wet climate (EWR_S8) scenario predicts an increase of 0.20 m or 16 %.

Table 22 Change in Benden Road wetland water levels for wet, dry and historical wet climate change scenarios

Change in groundwater level compared to base case	S5		S7		S8	
	m	% change	m	% change	m	% change
AAMinGL	-0.12	40%	-0.60	211%	0.19	66%
AAMaxGL	-0.06	4%	-0.53	42%	0.20	16%

5.8 Risk of impact mapping

The risk of impact mapping for Benden Road wetland is displayed in Figure 12. The mapping displays high risk of impact for the AAmaxGL for scenarios S7 and S8 at the vegetation change locations. For scenario S7 AAminGL the risk of impact is mapped as moderate along the western edge and high for the adjacent vegetation change location and for the vegetation changes along the eastern edge of the wetland. For both scenarios S5 and S8 the western and eastern edges of the wetland transect are mapped as having low risk of impact, while adjacent vegetation change locations are mapped as moderate risk of impact.

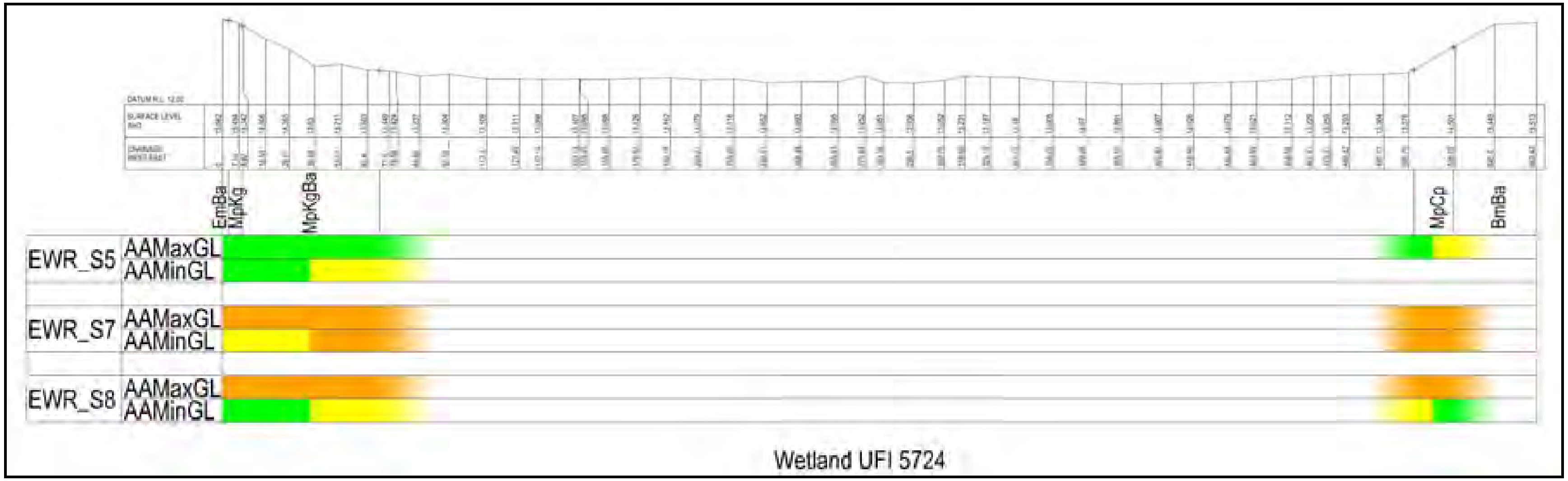


Figure 12 Benden Road wetland risk of impact mapping for climate change scenarios

6. Wetland UFI 5180 (Scott Road)

Scott Road Wetland (wetland UFI 5180 in the DEC Geomorphic Wetland Swan Coastal Plain dataset) is located close to the centre of the study area (Figure 13). The wetland is categorised as a resource enhancement wetland but was included as a key wetland for the EWR study due to the high level of vegetation diversity, quality and health that was observed during the site visit. The wetland is seasonally inundated, and is dry in summer months.

The wetland receives a small amount of surface water drainage from surrounding paddocks. A drainage channel is present south of the wetland which drains to the upper reaches of Winter Brook and eventually to the Murray River.

6.1 Background data

6.1.1 EPP Lakes

Wetland UFI 5180 is listed as an EPP Lake.

6.1.2 Previous studies

Bowman Bishaw Gorham (2006) interpolated ground water levels within the Nambeelup area based on observed water levels in 20 monitoring bores. Within the vicinity of the Scott Road wetland the ground water level was interpolated as approximately 12 mAHD in June 2006, which suggests that the wetland is inundated by superficial groundwater in winter months.

6.2 Site specific ecological data

The location of the ecological survey sites for Scott Road wetland are shown in Figure 13.

6.2.1 Vegetation and flora survey

The vegetation community types surveyed along the vegetation transect are described in Table 23. The native vegetation condition ranged between Pristine (1) to Completely Degraded (6). Native vegetation at the eastern end of the transect survey area rated Very Good to Completely Degraded. Clearing, weed invasion, tracks and cattle grazing were present at this section of the transect survey area. The western end of the transect survey area rated Pristine to Excellent, with minimal cattle grazing evident.

Table 23 Vegetation community types for Scott Road wetland

Vegetation community name	Vegetation community description	Elevation range (mAHD)	Rare and priority species
Mr Cr	Low open forest of *Melaleuca rhaphiophylla* with *Cassytha racemosa*.	10.80 -11.35	
Mr La	Closed forest of *Melaleuca rhaphiohylla* over open heath with *Leucopogon australis* over closed sedgeland with *Meeboldina scariosa*	11.35 – 12.50	

Vegetation community name	Vegetation community description	Elevation range (mAHD)	Rare and priority species
Em Kg	Open woodland of *Eucalyptus marginata* over tall open scrub of *Kunzea glabrescens* over herbland of *Dasypogon bromeliifolius* over grassland	12.50 -14.90	

6.2.2 Native fish and amphibian survey

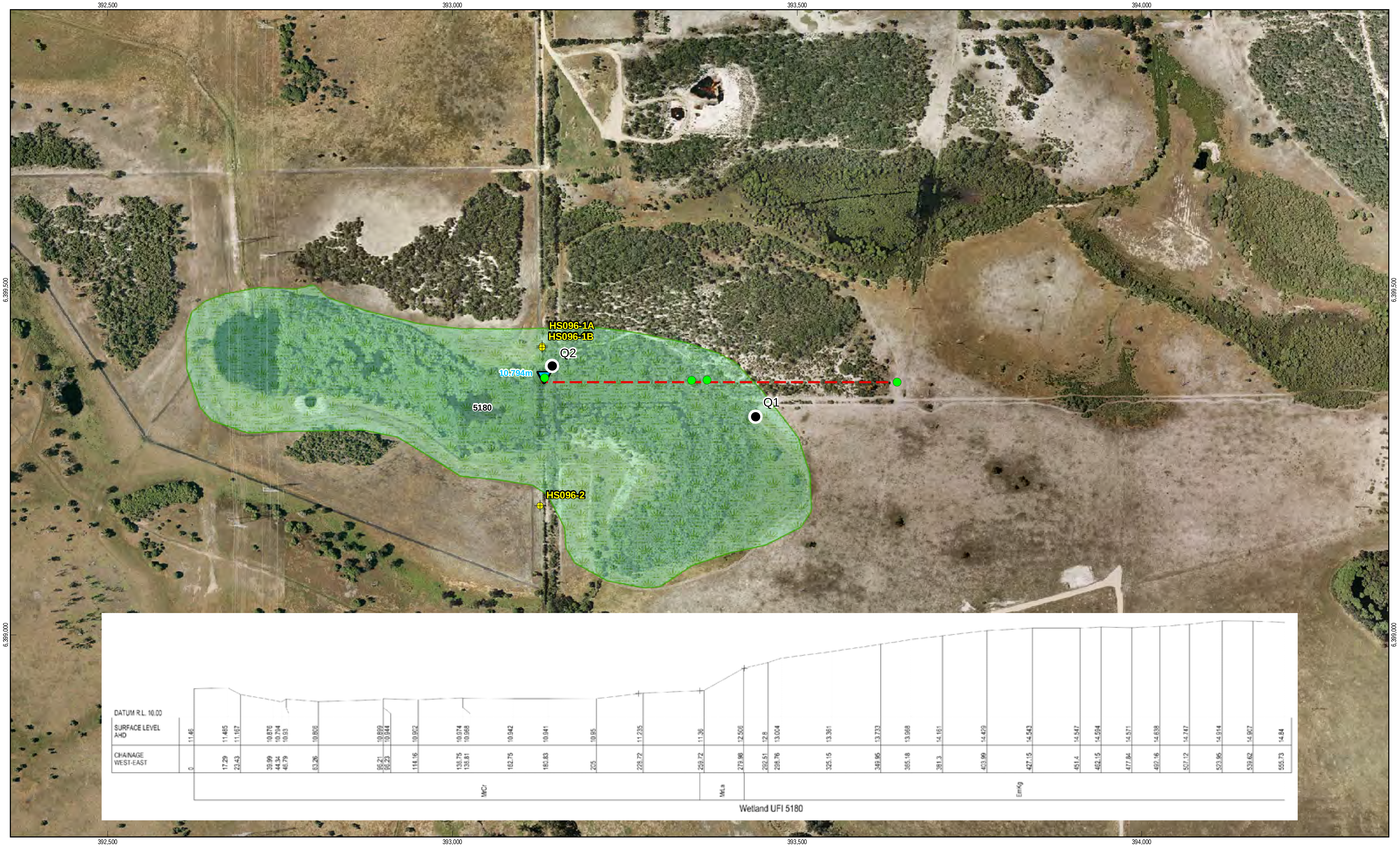
No native fish species were recorded. Five calling frog species were identified by their calls during the site specific survey. These were *Litoria adelaidensis, Crinia glauerti, C. insignifera, C. georgiana and Pseudophyne guentheri.*

6.3 Ecological values and environmental objectives

The ecological values, conceptual environmental management objectives and operational (measurable) environmental management objectives are based on the desktop assessment and site specific ecological surveys (Table 24). The operational environmental objectives for the wetland are determined for the vegetative components of the wetland due to the relatively transient nature of faunal populations and the difficulties associated with monitoring other ecosystem processes such as sediment processes. The established vegetation transect will enable future monitoring to determine if the operational environmental management objectives are being met.

Table 24 Ecological values and environmental objectives of Scott Road wetland

Conservation significance	Ecological value	Site specific values	Environmental objective	Operational environmental management objective
State REW DRF EPP Lake *Federal* EPBC Act	Wetland retains high ecological values Vegetation may contain conservation significant flora including rare and priority flora species Wetland ecosystem may contain habitat that supports significant fauna including threatened fauna and migratory bird species protected under the JAMBA and CAMBA agreements	Vegetation condition *Pristine* to *Completely Degraded*	To maintain biodiversity To maintain hydrological functions Protect the habitat of significant fauna	To maintain species composition To maintain species distribution To maintain species richness To control species mortality To maintain species condition and vigour To maintain community structure



1:5,000 (at A3)

0 25 50 100 150 200 250

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

- Vegetation Type Boundary
- Frog and Fish Assessment Points
- Borehole
- mAHD Lowest Surveyed Point
- Approximate Transect Line
- Roads

Geomorphic Wetlands

- Conservation
- Resource Enhancement
- Multiple Use
- Not Assessed
- Not Applicable

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Government of Western Australia
Department of Water

Department of Water
Murray Drainage and
Water Management Study

Wetland UFI 5180
Scott Road Wetland

Job Number	61-2393704
Revision	A
Date	30 AUG 2010

Figure 13

G:\61\2393706\GIS\mxds\612393704-G011_Figure 13 - Wetland UFI 5180 - Scott Road Wetland.mxd

GHD House, 239 Adelaide Terrace Perth WA 6004 **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Data Source: DEC: Geomorphic Wetlands, Swan Coastal Plain - 20070319; GHD: Approximate Transect Lines - 20090624; Landgate: Metro South 2009 Mosaic - 20090627; Landgate: Roads - 20090625; GHD: Murray Wetland Boreholes - 20100119, Lowest Surveyed Points - 20100330; GHD: Frog and Fish Assessment Points - 20090821, Murray Wetland Boreholes - 20100119, Lowest Surveyed Points - 20100330. Created by: kdiralu, jhchen

6.4 Description of water regime

6.4.1 Surface water

The surface water level within Scott Road wetland displays distinct seasonal fluctuations in response to climatic conditions Figure 14. The minimum surface water level in Scott Road wetland is 10.79 mAHD, corresponding with the lowest surveyed elevation point along the wetland transect. The wetland dries in all years. The maximum modelled surface water level is 11.73 mAHD (August 1991), and the lowest of the maximum water levels was modelled as 11.22 mAHD (September 2006), corresponding to a level of 11.10 mAHD at the PLI. The minimum and maximum surface water levels for the various periods are displayed in Table 25.

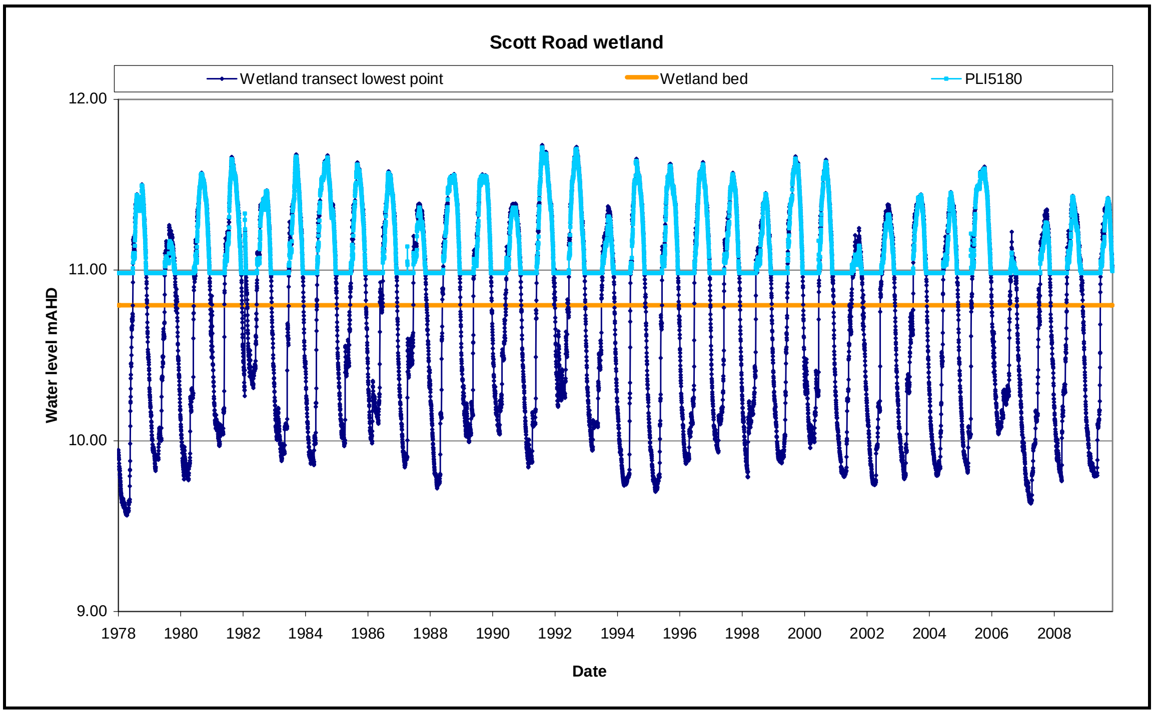


Figure 14 Modelled surface and ground water level in Scott Road wetland at the lowest point along the wetland transect and PLI

Table 25 Scott Road wetland modelled absolute and annual average minimum and maximum surface water level

Period	Minimum		Maximum	
	mAHD	mAGL	mAHD	mAGL
1978-2009	10.79	0.00	11.72	0.93
20 year annual average	10.79	0.00	11.47	0.68
10 year annual average	10.79	0.00	11.38	0.59
5 year annual average	10.79	0.00	11.36	0.57

Period	Minimum		Maximum	
	mAHD	mAGL	mAHD	mAGL
Timing	February-April		August-October	

6.4.2 Groundwater

Three bores were established at Scott Road wetland, a nest of two bores north of the wetland (HS096-1A and HS096-1B) and one bore south of the wetland (HS096-2) (Figure 13). The minimum and maximum groundwater levels and the general timing that these occur are outlined in Table 26.

Table 26 Scott Road wetland wetland modelled absolute and annual average minimum and maximum groundwater level

	HS096-1A		HS096-1B		HS096-2	
Minimum (mAHD)	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL
1978-2009	9.68	2.97	9.66	2.90	9.53	2.64
20 year annual average	9.98	2.67	9.96	2.60	9.77	2.40
10 year annual average	9.93	2.72	9.91	2.65	9.74	2.43
5 year annual average	9.91	2.74	9.89	2.67	9.73	2.44
Timing	March-April		February-April		February-April	
Maximum (mAHD)	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL
1978-2009	12.19	0.46	12.12	0.44	11.64	0.53
20 year annual average	11.77	0.88	11.77	0.79	11.39	0.78
10 year annual average	11.62	1.03	11.62	0.94	11.32	0.85
5 year annual average	11.60	1.05	11.60	0.96	11.31	0.86
Timing	August-October		August-October		July-September	

6.4.3 Annual period of drying

The modelled water level record was assessed to identify the annual period of drying, with summary statistics provided in Table 27. The summary statistics show that Scott Road wetland dries in all years, and has a historical maximum period of drying of 252 consecutive days in 2007 (over 8 months). When the whole period 1978-2009 is considered the wetland historically dries for over 6 months in 50% of years. For the period 2000-2009 Scott Road wetland dried for approximately 6.5 months in 50% of years.

Table 27 Scott Road wetland annual drying statistics

Annual drying statistics	1978-2009 (days)	2000-2009 (days)
Minimum	110	153
10th percentile	153	179

Annual drying statistics	1978-2009 (days)	2000-2009 (days)
30th percentile	165	186
50th percentile	183	197
70th percentile	189	208
90th percentile	207	215
Maximum	252	252

6.4.4 Water level magnitude of change

The modelled magnitude of change (increase and decrease) in minimum and maximum water level for Scott Road wetland is displayed in Table 28. The maximum annual increase and decrease in water levels between years were of the same magnitude for minimum and maximum water levels.

Table 28 Scott Road wetland magnitude of change in annual minimum and maximum water levels

	Minimum levels	Maximum levels
Maximum increase (m/year)	0.36 (1991-1992)	0.34 (1990-1991)
Maximum decrease (m/year)	-0.38 (1982-1983)	-0.40 (2000-2001)

6.4.5 Water quality

6.4.5.1 Physiochemical parameters

TDS in Scott Road wetland ranged from between 275 mg/L (August 2009) and 737 mg/L (December 2009). The pH ranged between 5.39 (December 2009) and 6.16 (August 2009).

6.4.5.2 Nutrients

Total nitrogen and total phosphorus samples were collected and analysed for a single snapshot monitoring event in September 2009. Concentrations were reported as 3.3 mg/L for TN and 0.35 mg/L for TP.

6.5 Water requirements to maintain vegetation communities

The water requirements for selected vegetation communities at Scott Road wetland are summarised below. Figures displaying the water requirements of vulnerable species as well as the existing water levels at the upper and lower elevation extent of the vegetation communities are located in Appendix D.

6.5.1 Vegetation community MrLa

To maintain the most vulnerable species for vegetation community MrLa (*Meeboldinia scariosa*) at a low level of risk a range in groundwater level of between 10.33 and 13.04 mAHD may be required based on the mean SW water level range for this species.

Modelled minimum groundwater levels at the lower elevation extent are similar to the mean minimum SW water level (Most vulnerable L min). The modelled water levels should therefore meet the requirements of the most vulnerable species at the lower elevation extent of this vegetation community. The mean minimum SW water level at the upper elevation extent of the community (Most vulnerable U min) is considerably higher than the known minimum water levels for this species in the south-west of WA. .

Based on the modelled water level data the vegetation community is regularly inundated at its lower elevation of 11.3 mAHD, however is not inundated at its upper elevation of 12.5 mAHD.

6.5.2 Vegetation community MrCr

To maintain the most vulnerable species for vegetation community MrCr (*Meeboldinia scariosa*) at a low level of risk a range in groundwater level of between 9.83 and 12.04 mAHD may be required based on the mean SW water level range for this species.

Modelled minimum groundwater level typically range between 10.00 and 10.35 mAHD at the lower and upper elevation extents of the vegetation community which falls between the mean minimum SW level at the upper and lower extents of the vegetation community (Most vulnerable U min and Most vulnerable L min). The modelled water levels should therefore meet the requirements of the most vulnerable species at the lower elevation extent of this vegetation community.

Based on the modelled water level data the vegetation community is inundated on an annual basis at its lower elevation of 10.8 mAHD, and is frequently inundated at the upper elevation extent of 11.5 mAHD.

6.6 Interim ecological water requirement to maintain the environmental objectives

The EWRs to maintain the environmental objectives of Scott Road wetland are summarised in Table 29. The EWRs are of an interim nature and are based on the modelled wetland water regime. Comparison of the maximum and minimum water level values identify that the interim EWRs are able to meet the water requirements of the vegetation communities as described in Section 6.5. It is assumed that maintenance of the water regime of the vegetation communities will ensure other ecological objectives of the wetland.

Table 29 Interim ecological water requirements for Scott Road wetland

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	Interim EWR	Limits of acceptable change
Maintain biodiversity of Scott Road wetland (Wetland UFI 5180)	Condition: Vegetation condition ranged from *Pristine* to *Completely Degraded*. Trend: Trend in vegetation condition not identified as only single survey	**Groundwater level**			
		Maximum	HS096-1A: 11.22 to 12.19 mAHD (11.62 mAHD) HS096-1B: 11.27 to 12.12 mAHD (11.62 mAHD) HS096-2: 11.14 to 11.64 mAHD (11.32 mAHD)	Timing: peak water levels generally between August and October	Limit unable to be set due to limited site specific data
		Minimum	HS096-1A:	Timing: minimum water levels generally	

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	Interim EWR	Limits of acceptable change
	conducted.		9.68 to 10.41 mAHD (9.93 mAHD) HS096-1B: 9.66 to 10.40 mAHD (9.91 mAHD) HS096-2: 9.53 to 10.11 mAHD (9.74 mAHD)	between February and April	
		Surface water level			
		Maximum	11.22 to 11.73 mAHD (11.45 mAHD) Maximum water level > 11.60 mAHD: At least 2 in 10 years	>11.60 mAHD in at least 2 out of 10 years Timing: peak water levels generally occur in August to October	Limit unable to be set due to limited site specific data
		Minimum	1978-2009: 10.79 mAHD (10.79 mAHD) *Note PLI set at 10.98 mAHD*	Timing: minimum water levels generally between February and April	
		Period of drying			
		Minimum	1978-2009: 110 days 2000-2009: 153 days	Wetland dries on an annual basis for period of between 110 and 252 consecutive days	Limit unable to be set due to limited site specific data
		Median	1978-2009: 183 days 2000-2009: 197 days		
		Maximum	252 consecutive days		
		Magnitude of change in water level			
		Maximum	Increase: 0.34 m/yr Decrease: 0.40 m/yr	Magnitude of change should not exceed historic levels. Peak levels should not occur in successive years. Water levels should not remain stable i.e. 0 m/yr magnitude of change in successive years.	Limit unable to be set due to limited site specific data
		Minimum	Increase: 0.35 m/yr Decrease: 0.38 m/yr		

6.7 Scenario assessment for Scott Road wetland

6.7.1 Sand dune analysis (EWR_S1)

The Scott Road wetland has a significant dune (5.5 m high) to the east, with further sand dunes located to the north-west and north-east of the wetland. WSB analysis of the change to wetland water regime based on the removal of the sand dunes identified a change to the average annual maximum wetland water level of 0.01 m corresponding to a 2.3% reduction in average maximum water level (Hall *et al.* 2010c).

6.7.2 Hydrologic zone analysis (EWR_S2, EWR_S3 and EWR_S4)

As for Benden Road (Section 5.7.2).

6.7.3 Climate scenarios (EWR_S5, EWR_S7 and EWR_S8)

The effect of climate change on the minimum and maximum water level depth for Scott Road wetland is displayed in Table 30.

6.7.3.1 Minimum water levels

The assessment of climate change scenarios on minimum water levels identified that the wet climate (EWR_S5) achieves a 5% decline in annual average minimum water level from the base case, while the historical wet climate (EWR_S8) scenario predicts a 15% decline. This result appears anomalous however in many years the model predicts a lower minimum groundwater level for the historical wet climate scenario for Scott Road wetland when compared to the base case scenario. For the dry climate scenario (EWR_S7) the predicted change is a decline of approximately 0.40 m (42% change).

6.7.3.2 Maximum water levels

The wet climate scenario (EWR_S5) and historical wet climate scenarios predict a 4% decline and increase in annual average maximum water level from the base case respectively. For the dry climate (EWR_S7) the predicted change in maximum water level is 45%, a decline of over 0.30 m.

Table 30 Change in Scott Road wetland water levels for wet, dry and historical wet climate change scenarios

Change in groundwater level compared to base case	S5		S7		S8	
	m	% change	m	% change	m	% change
AAMinGL	-0.05	5%	-0.39	42%	-0.14	15%
AAMaxGL	-0.03	4%	-0.33	45%	0.03	4%

6.8 Risk of impact mapping

The risk of impact mapping for Scott Road wetland is displayed in Figure 15. The mapping shows low risk of impact for scenario S5 for both AAmaxGL and AAminGL, and for scenario S8 for AAminGL. The risk of impact is high for scenario S7 for AAmaxGL, and moderate to high for S7 AAminGL and S8 AAmaxGL.

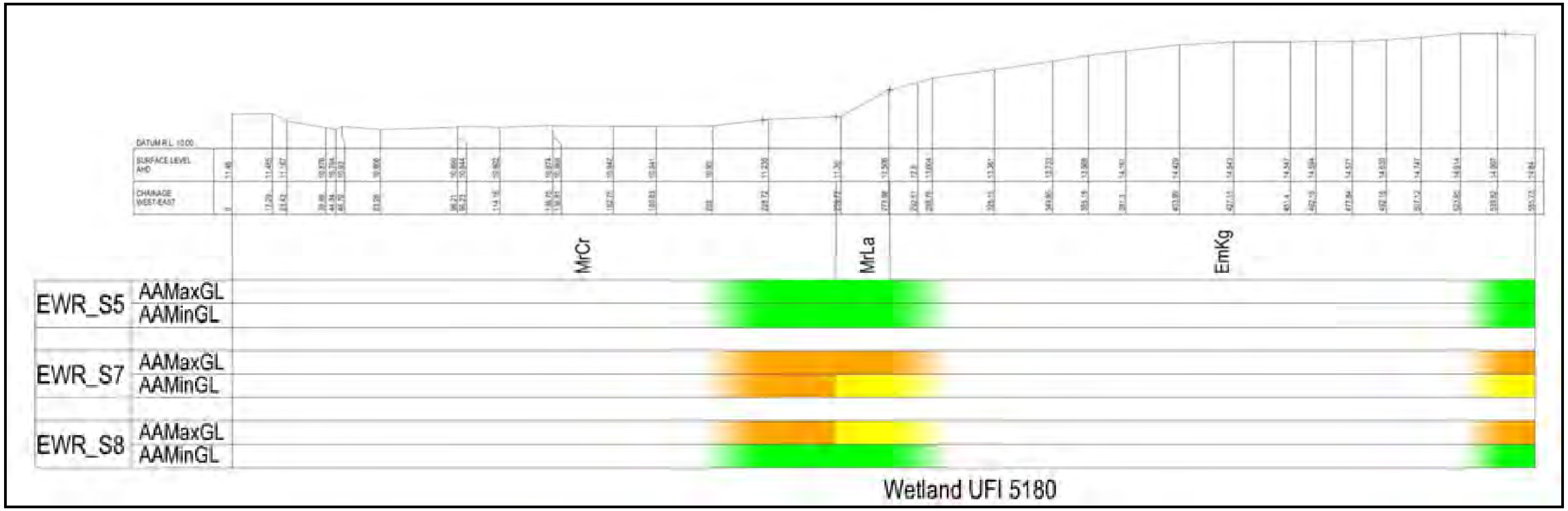


Figure 15 Scott Road wetland risk of impact mapping for climate change scenarios

7. Wetland UFI 7046 (Elliott Road)

The Elliott Road wetland, located in the north of the Murray DWMP area, comprises a number of individually identified wetland areas as categorised by the DEC Geomorphic Wetland Swan Coastal Plain dataset (wetland UFI 7046, 7029, 7027 and 7028). For the purposes of the EWR study the two conservation category classified areas located along the eastern ridge of the wetland are considered. Elliott Road North wetland (wetland UFI 7046 in the DEC Geomorphic Wetland Swan Coastal Plain dataset), is categorised as a conservation category sumpland. An upland portion of this wetland basin to the south is identified as Elliott Road South wetland (wetland UFI 7029 in the DEC Geomorphic Wetland Swan Coastal Plain dataset) which is categorised as a conservation category palusplain.

The Elliott Road wetland is adjacent to an aquaculture farm to the east, and is bounded by a ridge of vegetated sand dunes to the west, which marks the boundary of the Murray DWMP area.

Elliott Road Wetland is bounded artificially in the east by a levee bank, and two drains in the northern and southern portions of the levee bank which connects the wetland to a network of drains. The drains convey the water south towards Nambeelup Brook. The water level in the wetland is likely to be limited by the drain levels that intersect the wetland.

7.1 Background data

7.1.1 EPP Lakes

Wetland UFI 7046 is listed as an EPP Lake.

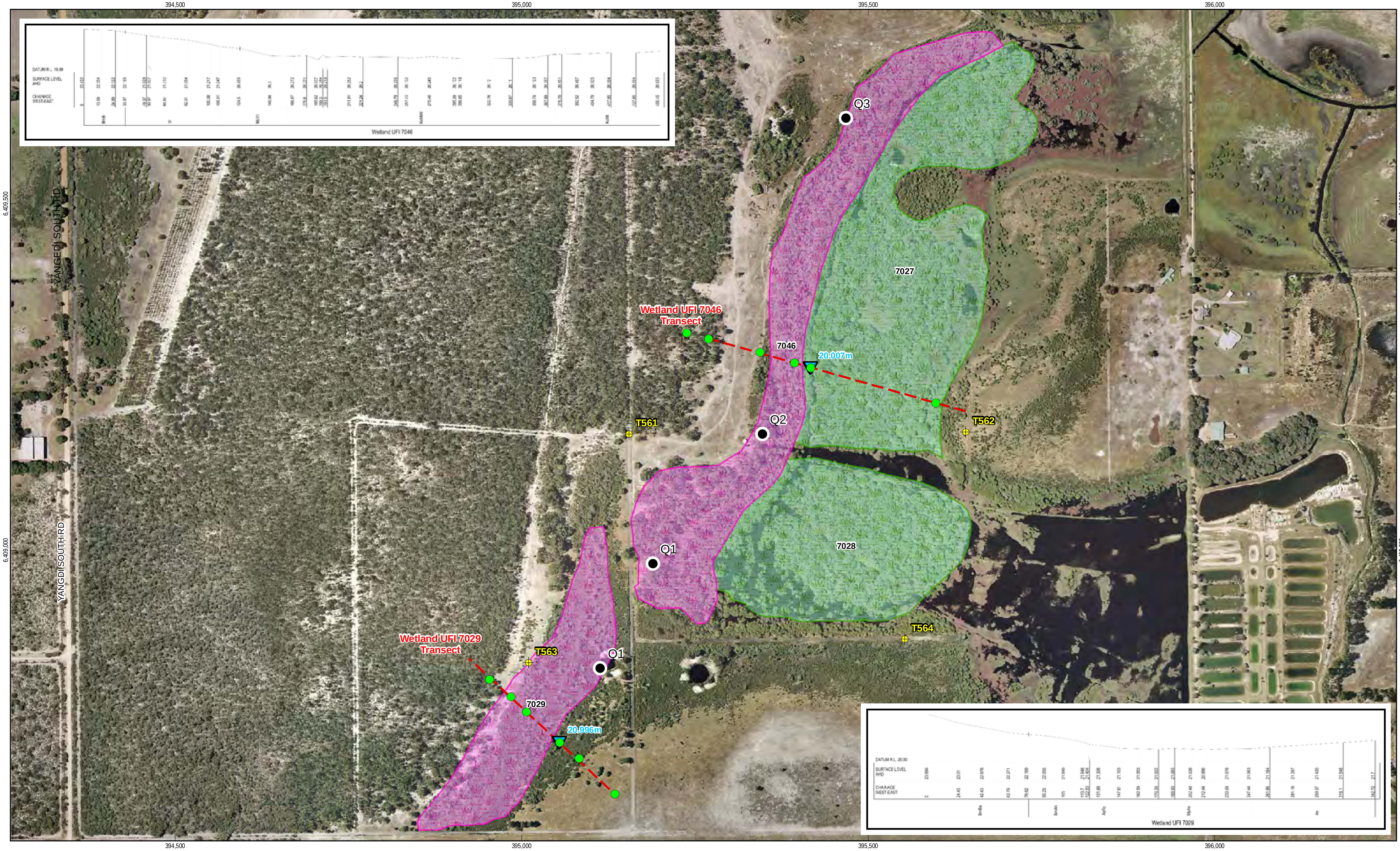
7.1.2 Bush Forever

The Elliott Road wetland occurs within the southern extent of Bush Forever site 77: Yangedi Swamp, Keysbrook. The site comprises 365 ha of bushland, which includes several conservation category (63.3 ha), resource enhancement and multiple use wetlands of the sumpland, dampland and palusplain types.

Bush Forever (2000) describes the vegetation condition as > 50% Very Good to Excellend, with localised areas of severe disturbance. Significant flora was listed to include *Stylidium longitubum* (P3), *Myriocephalus helichrysoides*, *Stylidium utricularoides* and *Macarthuria apetala* (most southern location).

7.2 Site specific ecological data

The location of the wetland transects and the ecological survey sites for the Elliott Road North and South wetlands are shown in Figure 16.



1:5,000 (at A3)

0 25 50 100 150 200 250

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

- Vegetation Type Boundary
- Frog and Fish Assessment Points
- Borehole
- mAHD Lowest Surveyed Point
- Approximate Transect Line
- Roads

Geomorphic Wetlands

- Conservation
- Resource Enhancement
- Multiple Use
- Not Assessed
- Not Applicable

GHD CLIENTS | PEOPLE | PERFORMANCE

Government of Western Australia Department of Water

Department of Water
Murray Drainage and
Water Management Study
Wetlands UFI 7046
And UFI 7029
Elliott Road North & South Wetlands

Job Number	61-2393704
Revision	A
Date	30 AUG 2010

Figure 16

G:\61\2393706\GIS\mxds\612393704-G008_Figure 16 - Wetland 7046 Elliott Road North Wetland.mxd

GHD House, 239 Adelaide Terrace Perth WA 6004 **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Data Source: DEC: Geomorphic Wetlands, Swan Coastal Plain - 20070319; GHD: Approximate Transect Lines - 20090624; Landgate: Metro South 2009 Mosaic - 20090627; Landgate: Roads - 20090625; GHD: Murray Wetland Boreholes - 20100119, Lowest Surveyed Points - 20100330. Created by: kdiralu, jhchen

7.2.1 Vegetation and flora survey

7.2.1.1 Elliott Road North

The vegetation community types surveyed along the vegetation transect for Elliott Road North are described in Table 31. The native vegetation condition of the vegetation transect for Elliott Road North wetland ranged between Very Good (3) to Completely Degraded (6). Areas towards the boundary of the wetland rated Degraded to Completely Degraded. These areas had been cleared in the past and are dominated by weed species. Areas within the wetland rated Very Good to Good as cattle grazing (when the wetland is dry) and tracks were evident in these areas. Weeds are present throughout the wetland.

Table 31 Vegetation community types for Elliott Road North wetland

Vegetation community name	Vegetation community description[1]	Elevation range (mAHD)	Rare and priority species
Ke Mt	Tall open scrub of *Kunzea ericifolia* and *Melaleuca thymoides*. closed herbland and grassland	20.40 – 20.7	
Ke Mt Af	Tall open scrub of *Melaleuca rhaphiophylla* over very open herbland of aquatic *Azolla filiculoides* and *Lemna* sp.	20.40 - 20.30	
Mp Mr	Low open forest of *Melaleuca preissiana* and *Melaleuca rhaphiophylla* over open heath of *Melaleuca osullivanii* over herbland of *Cotula coronopifolia** and *Rumex* sp.	20.30 – 21.05	
*W	Herbland and open grassland of weeds	21.05 – 22.15	
Bm Bi	Low woodland of *Banksia menziesii* and *Banksia ilicifolia* over herbland of *Desmocladus flexuosus* and *Ursinia anthemoides**	22.15 – 22.45	

7.2.1.2 Elliott Road South

The vegetation community types surveyed along the vegetation transect for Elliott Road South are described in Table 32. The native vegetation condition ranged between Excellent (2) to Completely Degraded (6). Areas towards the boundary of the wetland rated as Degraded to Completely Degraded. These areas have been cleared in the past and are dominated by weed species. Cattle grazing was evident in these areas also. Weeds are present throughout the wetland. A small area of native vegetation to the north west of the survey transect is rated as Excellent with some evidence of grazing and some weeds.

Table 32 Vegetation community types for Elliott Road South wetland

Vegetation community name	Vegetation community description	Elevation range (mAHD)	Rare and priority species
Bm Ba	Low open forest of *Banksia menzeisii Banksia attenuata*	22.15 – 23.7	

[1] *Denotes introduced species

Vegetation community name	Vegetation community description	Elevation range (mAHD)	Rare and priority species
	and *Banksia ilicifolia* over herbland of *Desmocladus flexuosus* and mixed herbs		
Bm Ah	Isolated trees of *Banksia menziesii* and *Allocasuarina humilis* over open heath of *Regelia ciliata* over open herbland with *Desmocladus flexuosus* and *Dasypogon bromeliifolius* and grassland	21.55 - 22.15	
As Rc	Open heath of *Astartea scoparia*, *Regelia ciliata* and *Hypocalymma angustifolium* subsp *Swan Coastal* over very open herbland and grassland	21.0 -21.55	
Mp As	Open woodland of *Melaleuca preissiana* over tall scrub of *Astartea scoparia* and *Kunzea ericifolia* over open herbland and grassland.	21.1 -21.0	
As	Shrubland of *Astartea scoparia* over grassland of weeds and herbland of weeds.	21.0 – 21.7	

7.2.2 Native fish and amphibian survey

7.2.2.1 Elliott Road North

No native fish species were recorded. Four frog species were identified by their calls during the site specific survey. These were *Litoria adelaidensis, Crinia glauerti, C. insignifera* and *Lymnodynastes dorsalis*.

7.2.2.2 Elliott Road South

No native fish species were recorded. Two frog species were identified by their calls during the site specific survey. These were *Crinia glauerti* and *C. insignifera*.

7.3 Ecological values and environmental objectives

The ecological values, conceptual environmental management objectives and operational (measurable) environmental management objectives are based on the desktop assessment and site specific ecological surveys (

Table 33). The operational environmental objectives for the wetland are determined for the vegetative components of the wetland due to the relatively transient nature of faunal populations and the difficulties associated with monitoring other ecosystem processes such as sediment processes. The established vegetation transect will enable future monitoring to determine if the operational environmental management objectives are being met.

Table 33 Ecological values and environmental objectives of Elliott Road North and South wetlands

Conservation significance	Ecological value	Site specific values	Environmental objective	Operational environmental management objective
State CCW DRF EPP Lake (Elliott Road North) *Federal* EPBC Act	Wetland retains high ecological values Vegetation may contain conservation significant flora including rare and priority flora species Wetland ecosystem may contain habitat that supports significant fauna including threatened fauna and migratory bird species protected under the JAMBA and CAMBA agreements	Vegetation condition *Very Good* to *Completely Degraded* (Elliott Road North) Vegetation condition *Excellent* to *Completely Degraded* (Elliott Road South)	To maintain biodiversity To maintain hydrological functions Protect the habitat of significant fauna	To maintain species composition To maintain species distribution To maintain species richness To control species mortality To maintain species condition and vigour To maintain community structure

7.4 Description of water regime

The description of the water regime for the Elliott Road wetlands primarily considers the surface water regime of Elliott Road north wetland. The Elliott Road south wetland is located within the same topographical basin and therefore represents an upland extension of the Elliott Road north wetland.

7.4.1 Surface water

The surface water levels within the Elliott Road wetlands display distinct seasonal fluctuations in response to climatic conditions. Figure 17 displays the modelled surface and groundwater levels for the Elliott Road North wetland at the lowest surveyed elevation point along the wetland transect.

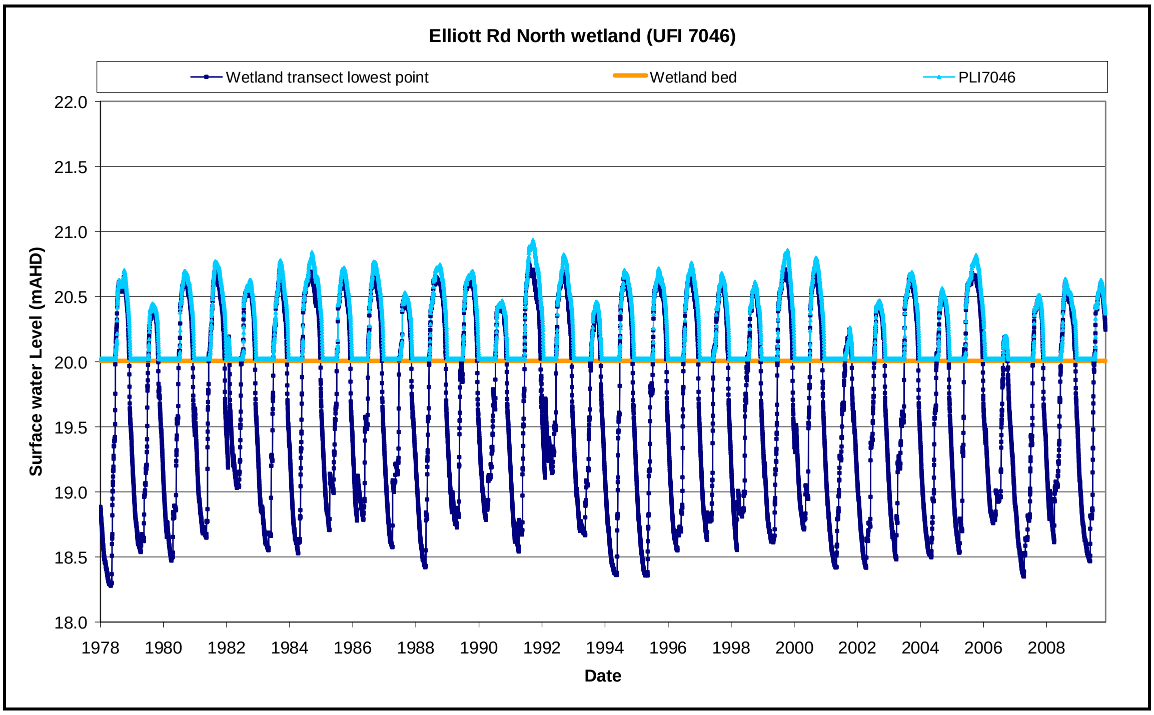


Figure 17 Modelled surface and ground water level for Elliott Road North wetland at the lowest point along the wetland transect and PLI

The minimum surface water level along the wetland transect is 20.01 mAHD in Elliott Road North wetland, and 21.00 mAHD in Elliott Road South wetland, corresponding with the lowest surveyed elevation point along the wetland transect. Based on the modelled data for the period 1978-2009 the wetland dries in all years. The absolute and annual average minimum and maximum surface water levels for various time periods are displayed in Table 34.

Table 34 Elliott Road North wetland modelled absolute and annual average minimum and maximum surface water level

Period	Minimum		Maximum	
	mAHD	mAGL	mAHD	mAGL
1978-2009 (absolute)	20.01	0.00	20.75	0.74
20 year annual average	20.01	0.00	20.56	0.55
10 year annual average	20.01	0.00	20.51	0.50
5 year annual average	20.01	0.00	20.51	0.50
Timing	October-December[1]		August-October	

[1] Timing of minimum level refers to the timing of wetland drying

7.4.2 Groundwater

Three bores were established around the Elliott Road North and South wetlands (T561, T563 and T564) and an additional bore immediately north of Elliott Road (T560S) (Figure 16). The minimum and maximum groundwater levels within the monitoring bores, and the general timing that these occur, are outlined in Table 35.

Table 35 Elliott Road wetlands monitoring bore minimum and maximum groundwater levels

	T560S		T561		T563		T564	
Minimum	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL
1978-2009 (absolute)	18.57	2.96	18.30	3.39	18.22	3.31	18.42	2.27
20 year annual average	18.61	2.92	18.37	3.32	18.25	3.28	18.46	2.23
10 year annual average	18.61	2.92	18.37	3.32	18.25	3.28	18.49	2.20
5 year annual average	18.61	2.92	18.37	3.32	18.25	3.28	18.49	2.20
Timing	March-April		March-May		March-April		March-May	
Maximum	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL
1978-2009	21.49	0.04	21.69	0.00	21.53	0.00	20.77	-0.08
20 year annual average	21.49	0.04	21.69	0.00	21.53	0.00	20.77	-0.08
10 year annual average	21.49	0.04	21.64	0.05	21.52	0.01	20.70	-0.01
5 year annual average	21.49	0.04	21.64	0.05	21.52	0.01	20.70	-0.01
Timing	August-September		August-October		August-October		August-October	

7.4.3 Annual period of drying

Modelled surface water data show that the Elliott Road North wetland is inundated on an annual basis (

Table 36). The summary statistics show that the Elliott Road North wetland has a modelled historical maximum period of drying of 293 consecutive days. When the whole period 1978-2009 is considered the model data show the wetland is historically dry for nearly 7 months in 50% of years. For the period 2000-2009 the model data show the wetland is dry for over 7 months in 50% of years.

Due to its more upland location the model data show the Elliott Road South wetland is drier than the Elliott Road North wetland (data not shown). The wetland model show that the Elliott Road South wetland is generally dry for a period of at least 2 months longer than the Elliott Road North wetland and remains dry in 1 in every 10 years for the period 1978-2009, or 3 in every ten years for the period 2000-2009.

Table 36 **Elliott Road North wetland annual drying statistics**

Annual drying statistics	1978-2009 (days)	2000-2009 (days)
Min	133	174
10th percentile	174	198
30th percentile	196	208
50th percentile	207	218
70th percentile	216	243
90th percentile	237	266
Max	293	293

7.4.4 Water level magnitude of change

The modelled magnitude of change (increase and decrease) in minimum and maximum water level for Elliott Road North wetland is displayed in Table 37. Rate of change data for the Elliott Road South wetland (not shown) indicate a larger decline in minimum and maximum water level, and a larger increase in maximum water level, between years compared to Elliott Road North wetland. The rate of increase in minimum water levels is of a similar magnitude for both wetlands.

Table 37 **Elliott Road North wetland magnitude of change in annual minimum and maximum water levels**

	Minimum levels	Maximum levels
Maximum increase (m/year)	0.57 (1991-1992)	0.32 (1990-1991)
Maximum decrease (m/year)	-0.48 (1982-1983)	-0.50 (2005-2006)

7.4.5 Water quality

7.4.5.1 Physiochemical parameters

TDS in Elliott Road North wetland ranged from between 208 mg/L (September 2009) and 1,123 mg/L (December 2009). A single TDS value was obtained from Elliott Road South wetland in September 2009 measuring 132 mg/L.

The pH in Elliott Road North wetland ranged between 6.54 (8^{th} December 2009) and 7.65 (21^{st} December 2009), with a single pH value of 7.20 recorded for Elliott Road South wetland on 11^{th} September 2009.

7.4.5.2 Nutrients

Total nitrogen and total phosphorus samples were collected and analysed for a single snapshot monitoring event in September 2009. The concentrations were reported as 1.7 mg/L for TN and 0.69 mg/L for TP for Elliott Road North wetland, and 2.2 mg/L for TN and 0.43 mg/L for TP for Elliott Road South wetland.

7.5 Water requirements to maintain vegetation communities

The water requirements for selected vegetation communities at Elliott Road North and South wetlands are summarised below. Figures displaying the water requirements of vulnerable species as well as the existing water levels at the upper and lower elevation extent of the vegetation communities are located in Appendix D.

7.5.1 Elliott Road North

7.5.1.1 Vegetation community BmBi

To maintain the most vulnerable species for vegetation community BmBi (*Banksia illicifolia*) at a low level of risk a range in groundwater level of between 19.61 and 20.89 mAHD may be required based on the mean SW water level range for this species. Modelled minimum groundwater level typically range between 18.45 and 18.80 mAHD for both the lower and upper elevation extents of the vegetation community, which is below the mean minimum SW water levels (Most vulnerable U min and Most vulnerable L min). The modelled minimum groundwater levels are above the absolute minimum SW water levels for both the upper and lower elevation extents (Most vulnerable U min ABS and Most vulnerable L min ABS) and therefore the water levels should meet the requirements of the most vulnerable species in this vegetation community.

Based on the modelled water level data the vegetation community is not inundated at its lower elevation of 22.20 mAHD or upper elevation of 22.45 mAHD.

7.5.1.2 Vegetation community MpMr

To maintain the most vulnerable species for vegetation community MrMr (*Juncus pallidus*) at a low level of risk a range in groundwater level of between 19.92 and 22.40 mAHD may be required based on the mean SW water level range for this species. Modelled minimum groundwater levels typically range between 18.25 and 18.70 mAHD, which is below the mean minimum SW water levels (Most vulnerable U min and Most vulnerable L min) and the absolute minimum SW water levels for the most vulnerable species at both the upper and lower elevation extent. The minimum water levels of the most vulnerable species may not be met by the modelled water regime.

Based on the modelled water level data the vegetation community is frequently inundated at its lower elevation of 20.30 mAHD, however is not inundated at its upper elevation of 21.95 mAHD.

7.5.1.3 Vegetation community KeMtAf

To maintain the most vulnerable species for vegetation community KeMtAf (*Juncus pallidus*) at a low level of risk a range in groundwater level of between 19.79 and 21.17 mAHD may be required based on the mean SW water level range for this species.

Modelled minimum groundwater levels typically range between 18.25 and 18.70 mAHD at the lower elevation extent, and 18.60 and 18.90 mAHD at the upper elevation extent. These modelled minimum groundwater values are below the mean minimum SW water levels (Most vulnerable U min and Most vulnerable L min) and the absolute minimum SW water levels for the most vulnerable species at both the upper and lower elevation extent. The minimum water levels of the most vulnerable species may not be met by the modelled water regime.

Based on the modelled water level data the vegetation community is inundated on an annual basis at its lower elevation of 20.15 mAHD, however is not inundated at its upper elevation of 20.70 mAHD.

7.5.2 Elliott Road South

7.5.2.1 Vegetation community BmBa

To maintain the most vulnerable species for vegetation community BmBa (*Banksia attenuata*) at a low level of risk a range in groundwater level of between 20.93 and 23.42 mAHD may be required based on the mean SW water level range for this species.

Modelled minimum groundwater level typically range between 18.50 and 18.90 mAHD at the lower elevation extent and 18.70 and 19.05 mAHD at the upper elevation extent of the vegetation community. These modelled water levels are below the mean minimum SW water levels (Most vulnerable U min and Most vulnerable L min) and the absolute minimum SW water levels for the most vulnerable species at both the upper and lower elevation extent.

Based on the modelled water level data the vegetation community is not inundated at its lower elevation of 22.15 mAHD or upper elevation of 23.70 mAHD.

7.5.2.2 Vegetation community As

To maintain the most vulnerable species for vegetation community As (*Melaleuca preissiana*) at a low level of risk a minimum groundwater level of between 18.70 and 21.00 mAHD may be required based on the mean SW water level range for this species. Existing minimum groundwater levels are of a similar magnitude however are considerably lower than the mean minimum SW water levels at the upper elevation extent of the vegetation community (Most vulnerable U min). The modelled minimum groundwater levels are above the absolute minimum SW water levels for both the upper and lower leveation extents (Most vulnerable U min ABS and Most vulnerable L min ABS) and therefore the water levels should meet the requirements of the most vulnerable species in this vegetation community.

Based on the modelled water level data the vegetation community is regulalrly inundated at its lower elevation of 21.00 mAHD, however is not inundated at its upper elevation of 21.70 mAHD.

7.6 Interim ecological water requirements to maintain the environmental objectives

The ERWs to maintain the environmental objectives of the Elliott Road wetland are summarised in Table 38. Where there are notable differences in aspects of the water regime between the Elliott Road North and South wetlands these have been specified.

The EWRs are of an interim nature and are based on the modelled wetland water regime. Comparison of the maximum and minimum water level values identify that the interim EWRs are able to meet the water requirements of most of the vegetation communities as described in Section 7.5.

However the modelled minimum water levels may not meet the minimum water requirements of the *most vulnerable species* for vegetation communities MpMr and KeMtAf for Elliott Road North wetland. It is assumed that maintenance of the water regime of the vegetation communities will ensure other ecological objectives of the wetland are maintained.

Table 38 Interim ecological water requirements for Elliott Road wetland

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	Interim EWR	Limits of acceptable change
Maintain biodiversity of Elliott Road wetland (Wetland UFI 7046 and 7029)	Condition: Vegetation condition ranged from *Excellent* to *Completely Degraded*. Trend: Trend in vegetation condition not identified as only single survey conducted.	**Groundwater level**			
		Maximum	T560S: 20.35 to 21.49 mAHD (21.18 mAHD) T561: 20.16 to 21.69 mAHD (21.03 mAHD) T563: 20.30 to 21.53 mAHD (21.14 mAHD) T564: 20.50 to 20.77 mAHD (20.65 mAHD)	Timing: peak water levels generally between August and October	Limit unable to be set due to limited site specific data
		Minimum	T560S: 18.57 to 19.13 mAHD (18.74 mAHD) T561: 18.30 to 18.99 mAHD (18.51 mAHD) T563: 18.22 to 18.85 mAHD (18.35 mAHD) T564: 18.42 to 19.10 mAHD (18.63 mAHD)	Timing: minimum water levels generally between March and May	
		Surface water level (Elliott Road North)			
		Maximum	20.19 to 20.75 mAHD (20.52 mAHD) Maximum water level > 20.80 mAHD: At least 1 in 10 years	> 20.80 mAHD in at least 1 out of 10 years Timing: peak water levels generally occur in September to October	Limit unable to be set due to limited site specific data
		Minimum	20.01 mAHD (20.01 mAHD)	Timing: minimum water levels generally between October and December	

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	Interim EWR	Limits of acceptable change
		Period of drying (Elliott Road North)			
		Minimum	Elliott Road North: 1978-2009: 133 days 2000-2009: 174 days	Wetland generally dries on an annual basis for period of between 133and 293 consecutive days	Limit unable to be set due to limited site specific data
		Median	1978-2009: 207 days 2000-2009: 218 days		
		Maximum	293 consecutive days		
		Magnitude of change in water level			
		Maximum	Increase: 0.32 m/yr Decrease: 0.50 m/yr	Magnitude of change should not exceed historic levels. Peak levels should not occur in successive years. Water levels should not remain stable i.e. 0 m/yr magnitude of change in successive years.	Limit unable to be set due to limited site specific data
		Minimum	Increase: 0.57 m/yr Decrease: 0.48 m/yr		

7.7 Scenario assessment for Elliott Road North

7.7.1 Hydrologic zone analysis (EWR_S2, EWR_S3 and EWR_S4)

The hydrologic zone analysis identified that in order to achieve a change in average wetland water level of les than 10% a minimum extent of between 200 and 300 m is required for drainage at AAMaxGL and drainage at 0.5 mBGL. For drainage at 1.0 mBGL a hydrologic zone extent of between 300 and 400 m was required.

7.7.2 Climate scenarios (EWR_S5, EWR_S7 and EWR_S8)

The effect of climate change on the minimum and maximum water level depth for Elliott Road North wetland is displayed in Table 39.

Minimum water levels

The assessment of climate change scenarios on minimum water levels identified that the wet climate (EWR_S5) achieves a 3% decline in annual average minimum water level from the base case, while the historical wet climate (EWR_S8) scenario predicts a 4% increase. For the dry climate scenario (EWR_S7) the predicted change is a decline of approximately 0.17 m (12% change).

Maximum water levels

The wet climate scenario (EWR_S5) predicts a 4% decline in annual average maximum water level from the base case, while the historical wet climate predicts a 6% increase in water level. For the dry climate (EWR_S7) the predicted change in maximum water level is 45%, a decline of 0.26 m.

Table 39 Change in Elliott Road North wetland water levels for wet, dry and historical wet climate change scenarios

Change in groundwater level compared to base case	S5		S7		S8	
	m	% change	m	% change	m	% change
AAMinGL	-0.04	3%	-0.17	12%	0.05	4%
AAMaxGL	-0.02	4%	-0.26	45%	0.04	6%

7.8 Scenario assessment for Elliott Road South

7.8.1 Hydrologic zone analysis (EWR_S2, EWR_S3 and EWR_S4)

As for Elliott Road North (Section 7.7.1).

7.8.2 Climate scenarios (EWR_S5, EWR_S7 and EWR_S8)

The effect of climate change on the minimum and maximum water level depth for Elliott Road South wetland is displayed in Table 50.

Minimum water levels

The assessment of climate change scenarios on minimum water levels identified that the wet climate (EWR_S5) scenario predicts a 1% decline in annual average minimum water level from the base case, while the historical wet climate (EWR_S8) scenario predicts a 2% increase. For the dry climate scenario (EWR_S7) the predicted change is a decline of approximately 0.13 m (5% change).

Maximum water levels

The wet climate scenario (EWR_S5) predicts a 35% decline in annual average maximum water level from the base case (0.05 m decline), while the historical wet climate predicts a 14% increase in water level. For the dry climate (EWR_S7) the predicted change in maximum water level is very high at 394%, a predicted decline of over 0.50 m.

Table 40 Change in Elliott Road South wetland water levels for wet, dry and historical wet climate change scenarios

Change in groundwater level compared to base case	S5		S7		S8	
	m	% change	m	% change	m	% change
AAMinGL	-0.04	1%	-0.13	5%	0.05	2%
AAMaxGL	-0.05	35%	-0.53	394%	0.02	14%

7.9 Risk of Impact Mapping

7.9.1 Elliott Road North

The risk of impact mapping for Elliott Road North wetland is displayed in Figure 18. The mapping shows low risk of impact for scenario S5 for both AAmaxGL and AAminGL, and for scenario S8 for AAminGL. The risk of impact is high for scenario S7 for AAmaxGL, moderate to high for S8 AAmaxGL and moderate for S7 AAminGL.

7.9.2 Elliott Road South

The risk of impact mapping for Elliott Road South wetland is displayed in Figure 19. The mapping shows low risk of impact for AAminGL for scenarios S5 and S8 and for the majority of the wetland transect for scenario S7 with the exception of the western vegetation community change location. For AAmaxGL the risk of impact mapping is moderate for scenario S5 and high for scenarios S7 and S8.

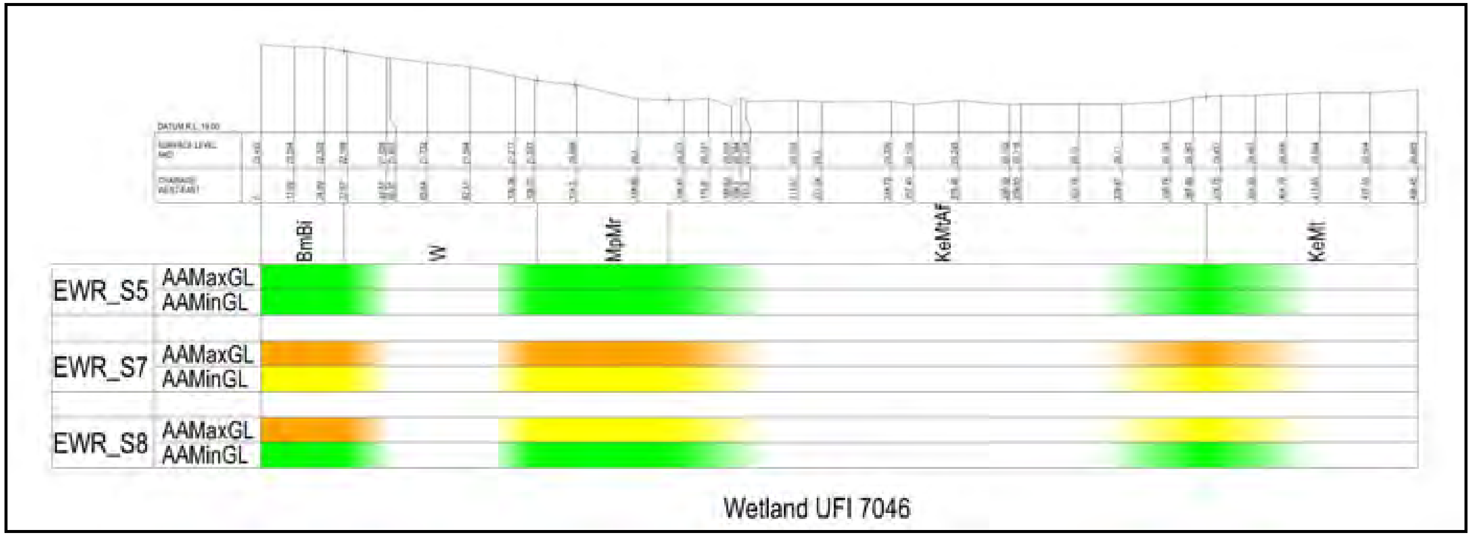


Figure 18 Elliott Road North wetland risk of impact mapping for climate change scenarios

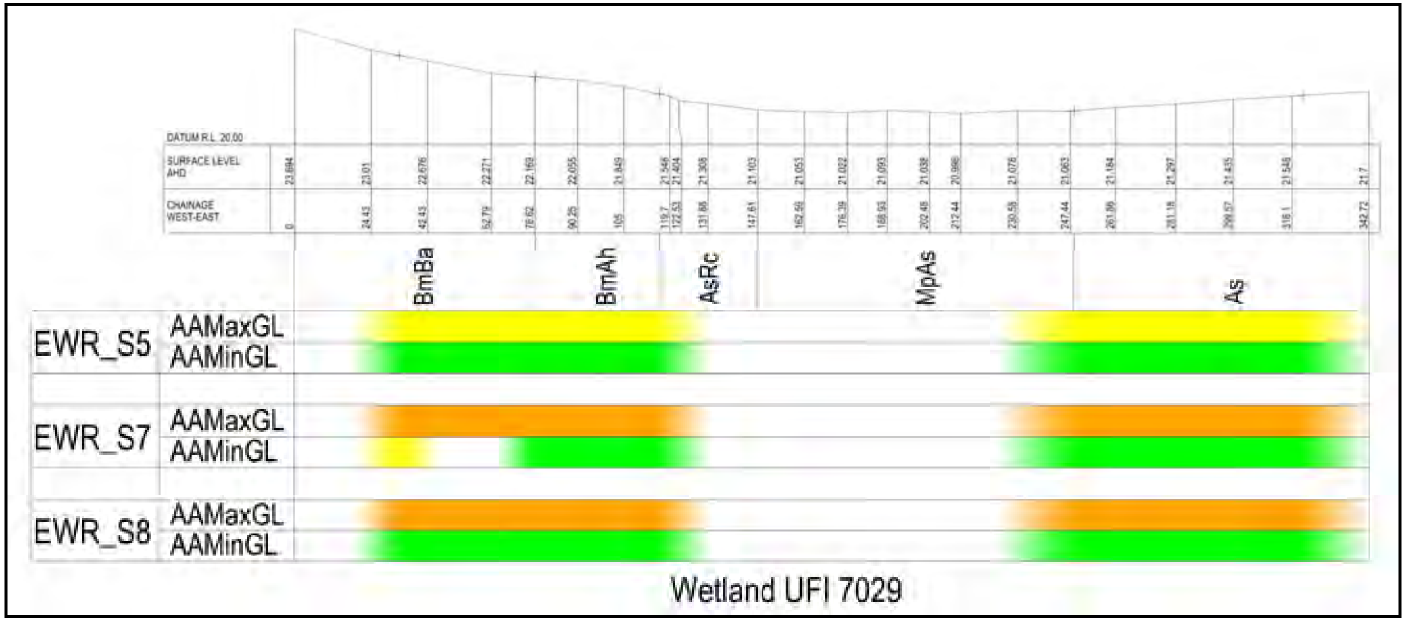


Figure 19 Elliott Road South wetland risk of impact mapping for climate change scenarios

8. Wetland UFI 4835 North (Airfield North) and South (Airfield South)

The Airfield Wetland (wetland UFI 4835 in the DEC Geomorphic Wetland Swan Coastal Plain dataset) is located adjacent to the Murrayfield private aerodrome. The wetland is categorised as a conservation category sumpland and is bisected by Lakes Road. Due to the presence of an elevated culvert and the different wetland vegetation communities observed during the wetland selection process this wetland had separate ecological transects established comprising Airfield North and Airfield South.

The wetland is seasonally inundated, and there are elevated culverts adjacent to Lakes Road, connecting the surface water of the northern and southern portion of the wetland. Surface water is likely to drain from the runway, located immediately north-east of the wetland, and enter the wetland. There is an existing drain in southern section of the wetland leading to Nambeelup Brook. However due to the high level of the invert in this drain outflow from the Airfield wetland flows to the north-west and west.

8.1 Background data

8.1.1 Previous studies

Parsons Brinkerhoff investigated shallow groundwater levels in the Nambeelup Strategic Industrial Area (Parsons Brinkerhoff 2008), which included Airfield Wetland. The report suggests that seasonally inundated areas are a surface expression of the groundwater, and the winter groundwater contours in the report suggest that the wetland is inundated by superficial groundwater in winter months.

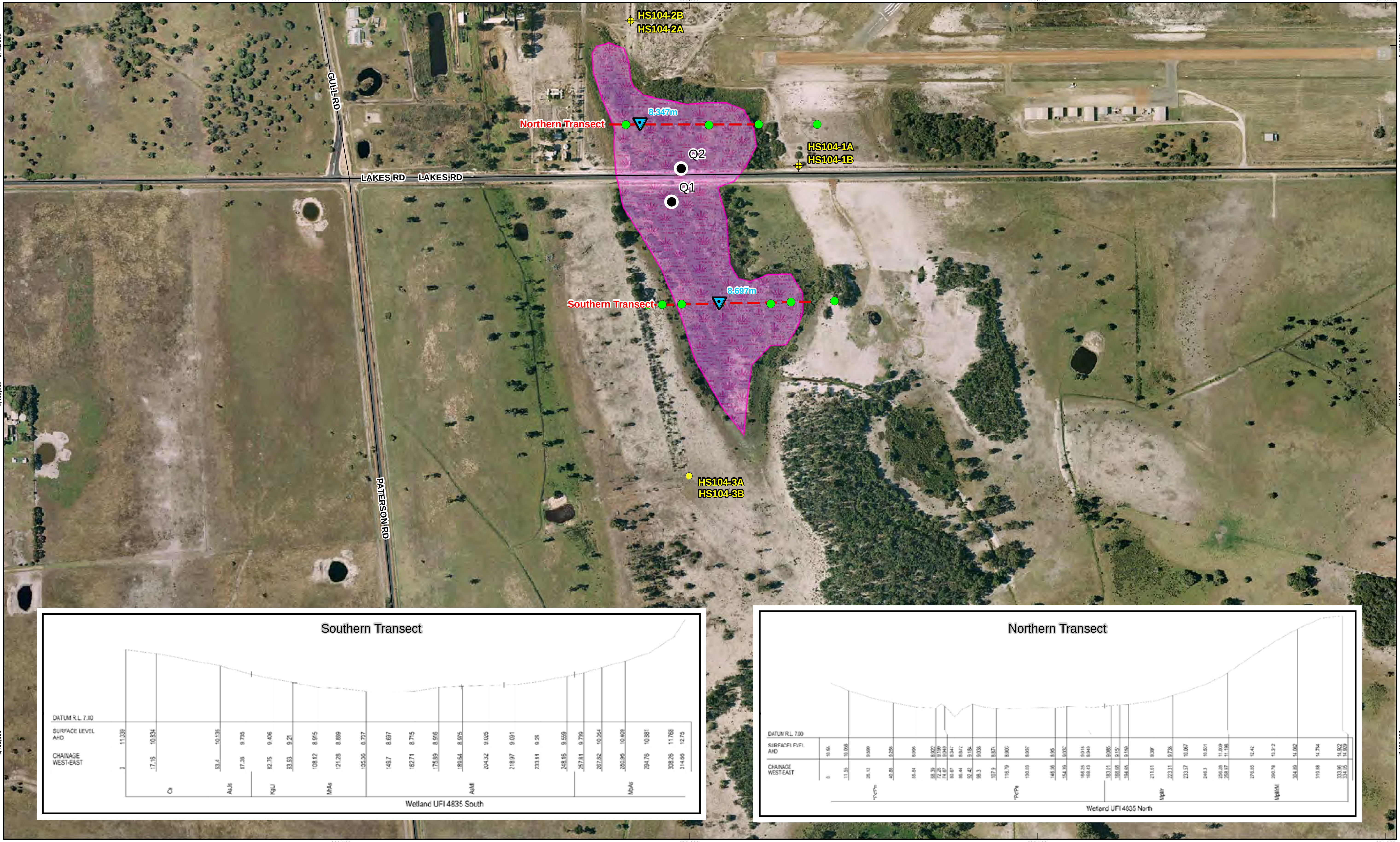
Bowman Bishaw Gorham (2006) interpolated groundwater levels within the Nambeelup area based on observed water levels in 20 monitoring bores. Within the vicinity of the Airfield wetland the ground water level was interpolated as approximately 8 to 9 mAHD in June 2006, which suggests that the wetland would be waterlogged or have some inundation by superficial groundwater in winter months.

8.2 Site specific ecological data

The location of the ecological survey sites for Airfield North and South wetland are shown in Figure 20.

8.2.1 Vegetation and flora survey for Airfield North

The vegetation community types surveyed along the vegetation transect are described in Table 41. The native vegetation condition ranged between Excellent (2) to Completely Degraded (6). Areas towards the boundary of the wetland were rated as Degraded to Completely Degraded. These areas have been cleared in the past and weed invasion has occurred. Rubbish was also present in these areas. The vegetation condition of the wetland itself was rated as Excellent to Very Good. The wetland has had some clearing.



1:5,000 (at A3)

0 25 50 100 150 200 250

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

- Vegetation Type Boundaries
- Frog and Fish Assessment Points
- Borehole
- mAHD Lowest Surveyed Point
- Approximate Transect Line
- Roads

Geomorphic Wetlands

- Conservation
- Resource Enhancement
- Multiple Use
- Not Assessed
- Not Applicable

GHD
CLIENTS | PEOPLE | PERFORMANCE

Government of Western Australia
Department of Water

Department of Water
Murray Drainage and
Water Management Study

Wetland UFI 4835
Airfield North and
South Wetland

Job Number	61-2393704
Revision	A
Date	30 AUG 2010

Figure 20

G:\61\2393706\GIS\mxds\612393704-G005_Figure 20 - Wetland UFI 4835 Airfield North and South Wetland.mxd

GHD House, 239 Adelaide Terrace Perth WA 6004 **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Data Source: DEC: Geomorphic Wetlands, Swan Coastal Plain - 20070319; GHD: Approximate Transect Lines - 20090624; Landgate: Metro South 2009 Mosaic - 20090627; Landgate: Roads - 20090625; GHD: Vegetation Type Boundaries - 20100327; GHD: Murray Wetlands - 20100205, Murray Wetland Boreholes - 20100119, Lowest Surveyed Points - 20100330. Created by: kdiralu, jhchen

8.2.1.1 Vegetation and flora survey for Airfield South

The vegetation community types surveyed along the vegetation transect are described in Table 42. The native vegetation condition ranged between Excellent (2) to Completely Degraded (6). Areas towards the boundary on the western edge of the wetland were rated as Degraded to Completely Degraded as it had been cleared in the past and is now dominated by weed species. Native vegetation on the eastern edge was rated as Excellent to Very Good with some clearing and cattle grazing evident. Native vegetation within the wetland was rated as Good to Very Good. Weed species and cattle grazing were evident.

Table 41 Vegetation community types for Airfield North wetland

Vegetation community name	Vegetation community description[1]	Elevation range (mAHD)	Rare and priority species
*Pc*Pm	**Pennisetum clandestinum* and *Phlaris minor* grassland over very open herbland of weed species	9.20 -10.50	
*Pc*Pe	**Pennisetum clandestinum* closed grassland and open herbland with **Pteridium esculentum*	8.90 – 9.20	
Mp Mr	Low open forest of *Melaleuca preissiana* and *Melaleuca rhaphiophylla* over open shrubland of *Melaleuca lateritia* and *Astartea scoparia* over closed sedgeland of *Lepidosperma longitudinale* and *Juncus pallidus*	8.90 – 10.55	
Mp Mr Ml	Low open woodland of *Melaleuca preissiana* and *Melaleuca rhaphiophylla* over open shrubland of *Melaleuca lateritia* and *Astartea scoparia* over closed sedgeland of *Lepidosperma longitudinale* and *Juncus pallidus*	14.90 -10.55	

Table 42 Vegetation community types for Airfield South wetland

Vegetation community name	Vegetation community description	Elevation range (mAHD)	Rare and priority species
Ca	Open herbland of *Conostylis aculeata* and weeds	10.30 -11.05	
As Js	Open heath of *Astartea scorparia* and *Jacksonia sternbergiana* and weeds	9.70 -10.30	
Kg Ll	Tall open scrub of *Kunzea glabrescens* over sedgeland with *Lepidosperma longitudinale* and *Microlaena stipoides*	9.15 – 9.70	
Mr As	Low open forest of *Melaleuca rhaphiophylla* over open shrubland of *Astartea scoparia, Melaleuca laterita* over closed sedgeland with *Lepidosperma longitudinale*	8.70 – 9.15	
As Ml	Open heath of *Astartea scoparia, Melaleuca laterita*	8.70 – 9.65	

[1] Denotes introduced species

Vegetation community name	Vegetation community description	Elevation range (mAHD)	Rare and priority species
	over sedgeland with *Lepidosperma longitudinale*		
Mp As	Closed tall scrub of *Melaleuca preissiana, Astartea scoparia* and *Hypocalymma angustifolium* sp. over closed sedgeland with *Meeboldinia scariosa and Hypolaena exsulca*	9.65- 12.50	

8.2.1.2 Native fish and amphibian survey

No native fish species were recorded. Four frog species were identified by their calls during the site specific survey. These were *Litoria adelaidensis, Crinia glauerti, C. insignifera* and *C. georgiana*.

8.3 Ecological values and environmental objectives of Airfield North and South wetlands

The ecological values, conceptual environmental management objectives and operational (measurable) environmental management objectives are based on the desktop assessment and site specific ecological surveys (Table 43). The operational environmental objectives for the wetland are determined for the vegetative components of the wetland due to the relatively transient nature of faunal populations and the difficulties associated with monitoring other ecosystem processes such as sediment processes. The established vegetation transect will enable future monitoring to determine if the operational environmental management objectives are being met.

Table 43 Ecological values and environmental objectives of Airfield North and South wetlands

Conservation significance	Ecological value	Site specific values	Environmental objective	Operational environmental management objective
State CCW DRF EPP Lake *Federal* EPBC Act	Wetland retains high ecological values Vegetation may contain conservation significant flora including rare and priority flora species Wetland ecosystem may contain habitat that supports significant fauna including threatened fauna and migratory bird species protected under the JAMBA and CAMBA agreements	Vegetation condition *Excellent* to *Completely Degraded* (Airfield North and South)	To maintain biodiversity To maintain hydrological functions Protect the habitat of significant fauna	To maintain species composition To maintain species distribution To maintain species richness To control species mortality To maintain species condition and vigour To maintain community structure

8.4 Description of water regime

The description of the water regime for the Airfield wetlands primarily considers the surface water regime of Airfield North wetland.

8.4.1 Surface water

Surface water levels within the Airfield North and South wetlands display distinct seasonal fluctuation in response to climatic conditions. Figure 21 displays the modelled surface and groundwater levels for the Elliott Road North wetland at the lowest surveyed elevation point along the wetland transect.

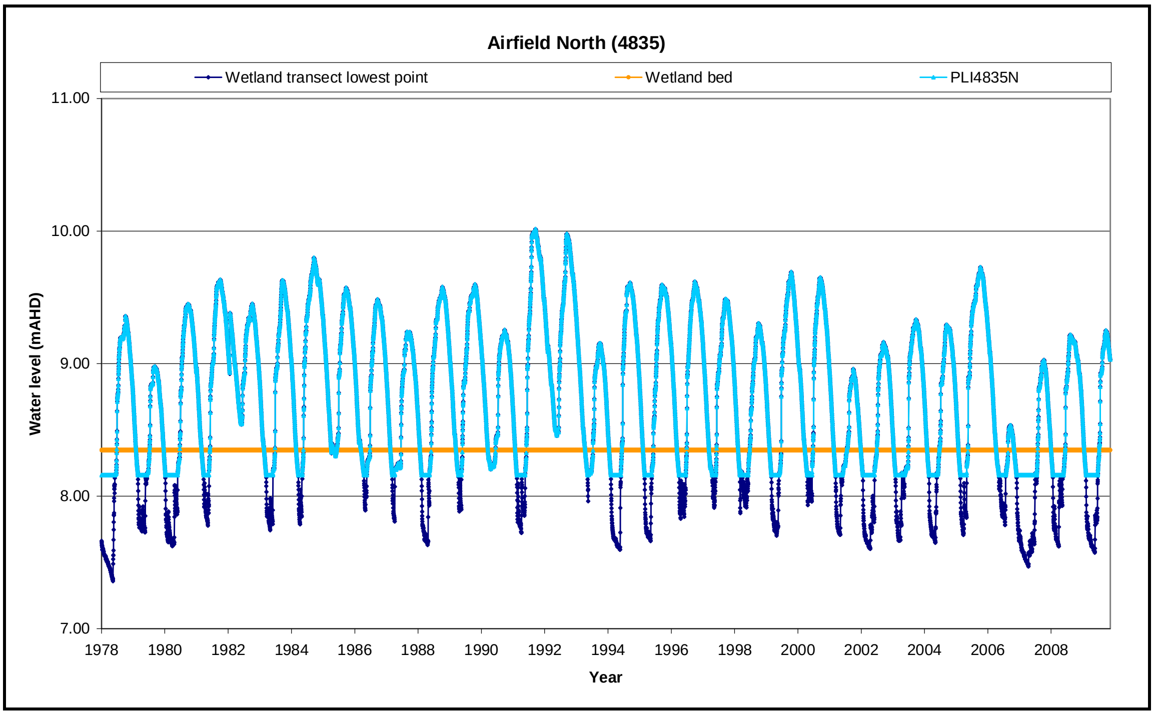


Figure 21 Modelled surface and ground water level in Airfield North wetland at the lowest point along the wetland transect and PLI

The minimum surface water level along the transect locations is 8.35 mAHD in Airfield North wetland and 8.70 mAHD in Airfield South wetland, corresponding with the lowest surveyed elevation point along the transect locations and drying of the wetland. The absolute and annual average minimum and maximum surface water levels for various time periods are displayed in Table 44.

Table 44 Airfield North wetland minimum and maximum surface water level

Period	Minimum		Maximum	
	mAHD	mAGL	mAHD	mAGL
1978-2009 (absolute)	8.35	0.00	10.02	1.67
20 year annual average	8.35	0.00	9.44	1.09
10 year annual average	8.35	0.00	9.29	0.94
5 year annual average	8.35	0.00	9.30	0.95
Timing	December-March		September-October	

8.4.2 Groundwater

Three nests of bores, comprising six bores in total, were established at the Airfield wetland. Two bores were established to the north of the wetland (HS104-2A and HS104-2B), two bores to the east of the wetland (HS104-1A and HS104-1B) and two bores to the south of the wetland (HS104-3A and HS104-3B) (Figure 20). The minimum and maximum groundwater levels and the general timing that these occur are outlined in Table 45.

Table 45 Airfield wetlands monitoring bore minimum and maximum groundwater levels

	HS104-1		**HS104-2A**		**HS104-2B**		**HS104-3A**		**HS104-3B**	
Minimum	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL
1978-2009 (absolute)	8.31	3.75	7.42	4.02	7.55	3.87	6.93	3.74	7.03	3.63
20 year annual average	8.99	3.07	7.93	3.51	8.10	3.32	7.34	3.33	7.50	3.16
10 year annual average	8.89	3.17	7.86	3.58	8.02	3.40	7.27	3.40	7.42	3.24
5 year annual average	8.82	3.24	7.80	3.64	7.97	3.45	7.23	3.44	7.38	3.28
Timing	March-May		March-May		March-May		March-May		March-May	
Maximum	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL
1978-2009 (absolute)	11.72	0.34	10.23	1.21	10.72	0.70	9.44	1.23	10.06	0.60
20 year annual average	10.87	1.19	9.63	1.81	9.98	1.46	8.93	1.74	9.39	1.27
10 year annual average	10.63	1.43	9.44	2.00	9.77	1.67	8.77	1.90	9.19	1.47
5 year annual average	10.58	1.48	9.37	2.07	9.71	1.73	8.72	1.95	9.13	1.53
Timing	July-September		August-September		July-September		August-September		July-September	

8.4.3 Annual period of drying

Surface water data show that the Airfield North wetland (

Table 46) and Airfield South wetland (data not shown) generally driy on an annual basis. The summary statistics show that the Airfield North wetland has a historical maximum period of drying of 271 consecutive days in 2007 (9 months). When the whole period 1978-2009 is considered the wetland is historically dry for over 4 months in 50% of years. For the period 2000-2009 Airfield North wetland was dry for over 5 months in 50% of years. Airfield South wetland is historically dry for a period of 0.5 to 1 month longer than Airfield North weltand (data not shown).

Table 46 Airfield North wetland annual drying statistics

Annual drying statistics	1978-2009 (days)	2000-2009 (days)
Minimum	0	92
10th percentile	75	106
30th percentile	97	139
50th percentile	127	154
70th percentile	144	170
90th percentile	175	192
Maximum	271	271

8.4.4 Water level magnitude of change

The modelled magnitude of change (increase and decrease) in minimum and maximum water level for Airfield North wetland is displayed in Table 47. The maximum magnitude of change was the same for both minimum and maximum water levels. For Airfield South wetland the magnitude of change in maximum water levels are identical to Airfield North wetland, however the magnitude of change in minimum water levels is smaller (0.3 m) than Airfield North (data not shown).

Table 47 Airfield North wetland magnitude of change in annual minimum and maximum water levels

	Minimum levels	Maximum levels
Maximum increase (m/year)	0.76 (1981-1982)	0.76 (1990-1991)
Maximum decrease (m/year)	-0.80 (1982-1983)	-0.69 (2000-2001)

8.4.5 Water quality

8.4.5.1 Physiochemical parameters

TDS ranged from between 116 mg/L (September 2009) and 165 mg/L (December 2009) in Airfield North wetland, and 139 mg/L (August 2009) and 250 mg/L (December 2009) in Airfield South wetland.

The pH in Airfield North wetland ranged between 5.60 (September 2009) and 6.31 (November 2009), and 7.09 (October 2009) and 7.32 (August 2009) in Elliott Road South.

8.4.5.2 Nutrients

Total nitrogen and total phosphorus samples were collected and analysed for a single snapshot monitoring event in September 2009. The concentrations were reported as 2.0 mg/L for TN and 0.15mg/L for TP for Airfield North wetland and 1.8 mg/L for TN and 0.06 mg/L for TP for Airfield South wetland.

8.5 Water requirements to maintain vegetation communities

The water requirements for selected vegetation communities at Airfield North and South wetlands are summarised below. Figures displaying the water requirements of vulnerable species as well as the existing water levels at the upper and lower elevation extent of the vegetation communities are located in Appendix D.

8.5.1 Airfield North

8.5.1.1 Vegetation community MpMr

To maintain the most vulnerable species for vegetation community MpMr (*Juncus pallidus*) at a low level of risk a range in groundwater level of between 8.52 and 11.00 mAHD may be required based on the mean SW water level range for this species. Modelled minimum groundwater levels typically range between 7.30 and 7.60 mAHD at the lower elevation extent, and 7.90 and 8.40 mAHD at the upper elevation extent of the vegetation community. A minimum groundwater level of 7.40 mAHD should meet the requirements of the most vulnerable species. Maximum groundwater levels should not exceed 9.70 mAHD for the vegetation community. These modelled minimum groundwater levels are below the mean minimum SW water levels (Most vulnerable U min and Most vulnerable L min) for the upper and lower elevation extents, and below the the absolute minimum SW water levels for the upper extent (Most vulnerable U min ABS). They are of the same magnitude as the absolute minimum SW water levels for the lower elevation extent of the vegetation community (Most vulnerable L min ABS) and therefore should meet the requirements of the most vulnerable species at the lower elevation extent of this vegetation community.

Based on the modelled water level data the vegetation community is frequently inundated at its lower elevation of 8.90 mAHD, however is not inundated at its upper elevation of 10.55 mAHD.

8.5.1.2 Vegetation community MpMrMl

To maintain the most vulnerable species for vegetation community MrCr (*Juncus pallidus*) at a low level of risk a range in groundwater level of between 10.17 and 15.35 mAHD may be required based on the mean SW water level range for this species. Modelled minimum groundwater levels typically range between 8.25 and 8.85 mAHD which is below the mean minimum SW water levels (Most vulnerable U min and Most vulnerable L min) for the upper and lower elevation extents, and below the the absolute minimum SW water levels for the upper and lower elevation extents (Most vulnerable U min ABS and Most vulnerable L min ABS). The minimum water levels of the most vulnerable species may not be met by the modelled water regime.

Based on the modelled water level data the vegetation community is occassionally inundated at its lower elevation of 10.55 mAHD, however is not inundated at its upper elevation of 14.90 mAHD.

8.5.2 Airfield South

The water requirements for selected vegetation communities at Airfield South wetland are summarised below. Figures displaying the water requirements of vulnerable species as well as the existing water levels at the upper and lower elevation extent of the vegetation communities are located in Appendix D.

8.5.2.1 Vegetation community AsMl

To maintain the most vulnerable species for vegetation community AsMl (*Meeboldinia scariosa*) at a low level of risk a range in groundwater level of between 7.73 and 10.19 mAHD may be required based on the mean SW water level range for this species. The modelled groundwater levels for the upper and lower elevation extents of the vegetation community are between the mean minimum and mean maximum SW water levels for the vegetation community (Most vulnerable max and Most vulnerable min) and therefore should meet the requirements of the most vulnerable species.

Based on the modelled water level data the vegetation community is inundated on an annual basis at its lower elevation of 8.70 mAHD, and is occasionally inundated at its upper elevation of 9.65 mAHD.

8.5.2.2 Vegetation community MpAs

To maintain the most vulnerable species for vegetation community MpAs (*Juncus pallidus*) at a low level of risk a range in groundwater level of between 9.27 and 12.95 mAHD may be required. Modelled minimum groundwater levels typically range between 7.35 and 7.85 mAHD at the lower extent, and 7.70 and 8.05 mAHD at the upper elevation extents of the vegetation community. These modelled minimum groundwater levels are below the mean minimum SW water levels (Most vulnerable U min and Most vulnerable L min) for the upper and lower elevation extents, and below the the absolute minimum SW water levels for the upper and lower elevation extents (Most vulnerable U min ABS and Most vulnerable L min ABS). The minimum water levels of the most vulnerable species may not be met by the modelled water regime.

Based on the modelled water level data the vegetation community is occassionally inundated at its lower elevation of 9.65 mAHD, however is not inundated at its upper elevation of 12.50 mAHD.

8.6 Interim ecological water requirements to maintain the environmental objectives

The EWRs to maintain the environmental objectives of the Airfield wetland are summarised in

Table 48. Where there are notable differences in aspects of the water regime between the Airfield North and South wetlands these have been specified.

The EWRs are of an interim nature and are based on the modelled wetland water regime. Comparison of the maximum and minimum water level values identify that the interim EWRs are able to meet the water requirements of most of the vegetation communities as described in Section 8.4.5. However the modelled minimum water levels may not meet the minimum water requirements of the *most vulnerable species* for vegetation community MpMrMl for Airfield North wetland, and for vegetation community MpAs for Airfield South wetland. It is assumed that maintenance of the water regime of the vegetation communities will ensure other ecological objectives of the wetland are maintained.

Table 48 Interim ecological water requirements for Airfield North wetland

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	EWR	Limits of acceptable change
Maintain biodiversity of Airfield North wetland (Wetland UFI 4835)	Condition: Vegetation condition ranged from *Excellent* to *Completely Degraded*. Trend: Trend in vegetation condition not identified as only single survey conducted.	**Groundwater level**			
		Maximum	HS104-1: 10.10 to 11.72 mAHD (10.63 mAHD) HS104-2A: 8.82 to 10.22 mAHD (9.44 mAHD) HS104-2B: 9.18 to 10.72 mAHD (9.77 mAHD) HS104-3A: 8.24 to 9.44 mAHD (8.77 mAHD) HS104-3B: 8.55 to 10.06 mAHD (9.19 mAHD)	Timing: peak water levels generally between July and September	Limit unable to be set due to limited site specific data
		Minimum	HS104-1: 8.31 to 9.58 mAHD (8.89 mAHD) HS104-2A: 7.42 to 8.38 mAHD (7.86 mAHD) HS104-2B: 7.55 to 8.59 mAHD (8.02 mAHD) HS104-3A: 6.93 to 7.74 mAHD (7.27 mAHD) HS104-3B: 7.03 to 7.94 mAHD (7.42 mAHD)	Timing: minimum water levels generally between March and May	
		Surface water level			
		Maximum	8.96 to 10.01 mAHD (9.29 mAHD) Maximum water level > 9.70 mAHD: At least 1 in 10 years	> 9.70 mAHD in at least 1 out of 10 years Timing: peak water levels generally occur in September to	Limit unable to be set due to limited site specific data

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	EWR	Limits of acceptable change
				October	
		Minimum	Airfield North: 8.35 to 8.54 mAHD (8.35 mAHD) *Note PLI set at 8.16 mAHD* Airfield South: 8.70 mAHD (8.70 mAHD) *Note PLI set at 8.68 mAHD*	Timing: minimum water levels generally between December to March	
		Period of drying (Airfield North)			
		Minimum	Airfield North: 1978-2009: 0 days 2000-2009: 92 days	Permanent water not present for more than 1 year Wetland generally dries on an annual basis for period of between 92 and 271 consecutive days	Limit unable to be set due to limited site specific data
		Median	1978-2009: 127 days 2000-2009: 154 days		
		Maximum	271 consecutive days		
		Period of drying (Airfield South)			
		Minimum	1978-2009: 24 days 2000-2009: 118 days	Wetland dries on an annual basis for period of between 24 and 291 consecutive days	Limit unable to be set due to limited site specific data
		Median	1978-2009: 150 days 2000-2009: 176 days		
		Maximum	291 consecutive days		
		Magnitude of change in water level			
		Maximum	Increase: 0.76 m/yr Decrease: 0.69 m/yr	Magnitude of change should not exceed historic levels.	Limit unable to be set due to limited site specific data
		Minimum	Airfield North: Increase: 0.76 m/yr Decrease: 0.80 m/yr Airfield South: Increase: 0.47 m/yr	Peak levels should not occur in successive years. Water levels should not remain stable i.e. 0 m/yr magnitude of	

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	EWR	Limits of acceptable change
			Decrease: 0.48 m/yr	change in successive years.	

8.7 Scenario assessment for Airfield North

8.7.1 Sand dune analysis (EWR_S1)

The Airfield wetland has significant dunes (6 m high) to the north, south and east of the wetland. DoW WSB analysis of the change to wetland water regime based on the removal of the sand dunes identified a change to the average annual maximum wetland water level of 0.01 m corresponding to a 0.7% reduction in average maximum water level for Airfield North wetland (Hall *et al.* 2010c).

8.7.2 Hydrologic zone analysis (EWR_S2, EWR_S3 and EWR_S4)

The hydrologic zone analysis identified that in order to achieve a change in average wetland water level of less than 10% a minimum extent of at least 100 m is required for drainage at 0.5 m, and at AAMaxGL. For drainage at 1 mBGL an extent of approximately 500 m is required.

8.7.3 Climate scenarios (EWR_S5, EWR_S7 and EWR_S8)

The effect of climate change on the minimum and maximum water level depth for Airfield North wetland is displayed in Table 49.

Minimum water levels

The assessment of climate change scenarios on minimum water levels identified that the wet climate (EWR_S5) achieves an 11% decline in annual average minimum water level from the base case, while the historical wet climate (EWR_S8) scenario predicts a 34% increase. For the dry climate scenario (EWR_S7) the predicted change is a decline of approximately 0.25 m (52% change).

Maximum water levels

The wet climate scenario (EWR_S5) predicts a 5% decline in annual average maximum water level from the base case, while the historical wet climate predicts a 34% increase in water level. For the dry climate (EWR_S7) the predicted change in maximum water level is 49%, a decline of nearly 0.55 m.

Table 49 Change in Airfield North wetland water levels for wet, dry and historical wet climate change scenarios

Change in groundwater level compared to base case	S5		S7		S8	
	m	% change	m	% change	m	% change
AAMinGL	-0.057	11%	-0.276	52%	0.180	34%
AAMaxGL	-0.053	5%	-0.540	49%	0.285	26%

8.8 Scenario assessment for Airfield South

8.8.1 Sand dune analysis (EWR_S1)

The Airfield wetland has significant dunes (6 m high) to the north, south and east of the wetland. DoW WSB analysis of the change to wetland water regime based on the removal of the sand dunes identified a change to the average annual maximum wetland water level of 0.01 m corresponding to a 1.1% reduction in average maximum water level for Airfield South wetland (Hall *et al.* 2010c).

8.8.2 Hydrologic zone analysis (EWR_S2, EWR_S3 and EWR_S4)

The hydrologic zone analysis identified that in order to achieve a change in average wetland water level of less than 10% a minimum extent of at least 300 m is required for drainage at AAMaxGL. The difference in hydrologic zone extent required for drainage at AAMaxGL between Airfield South (300 m buffer) and Airfield North (100 m buffer) is attributed to the relative changes in water level between the wetlands, as the northern part of the wetland is deeper (Hall *et al*. 2010c).

8.8.3 Climate scenarios (EWR_S5, EWR_S7 and EWR_S8)

The effect of climate change on the minimum and maximum water level depth for Airfield South wetland is displayed in Table 50.

Minimum water levels

The assessment of climate change scenarios on minimum water levels identified that the wet climate (EWR_S5) achieves a 5% decline in annual average minimum water level from the base case, while the historical wet climate (EWR_S8) scenario predicts a 9% increase. For the dry climate scenario (EWR_S7) the predicted change is a decline of approximately 0.25 m (33% change).

Maximum water levels

The wet climate scenario (EWR_S5) predicts a 7% decline in annual average maximum water level from the base case, while the historical wet climate predicts a 39% increase in water level. For the dry climate (EWR_S7) the predicted change in maximum water level is 64%, a decline of nearly 0.50 m.

Table 50 Change in Airfield South wetland water levels for wet, dry and historical wet climate change scenarios

Change in groundwater level compared to base case	S5		S7		S8	
	m	% change	m	% change	m	% change
AAMinGL	-0.035	5%	-0.231	33%	0.064	9%
AAMaxGL	-0.052	7%	-0.481	64%	0.293	39%

8.9 Risk of Impact Mapping

8.9.1 Airfield North

The risk of impact mapping for Airfield North wetland is displayed inFigure 22. The mapping shows high risk of impact for both AAmaxGL and AAminGL for scenario S7. For scenario S5 the risk of impact is low to moderate for AAmaxGL and AAminGL. For scenario S8 the AAmaxGL risk of impact varies between high in the western part of the wetland transect to low in the more elevated eastern part of the transect, while for AAminGL the risk of impact is moderate to low in the west and high in the eastern part of the wetland transect.

8.9.2 Airfield South

The risk of impact mapping for Airfield South wetland is displayed in Figure 23. The mapping shows high risk of impact for AAmaxGL for scenario S7 and S8. For scenario S5 for AAmaxGL the risk of impact ranged from low along the western edge of the transect to high and moderate. For AAminGL the risk of impact is low for scenario S5 and S8, and low to moderate for the western part of the wetland transect for S7 and high for the eastern part of the transect.

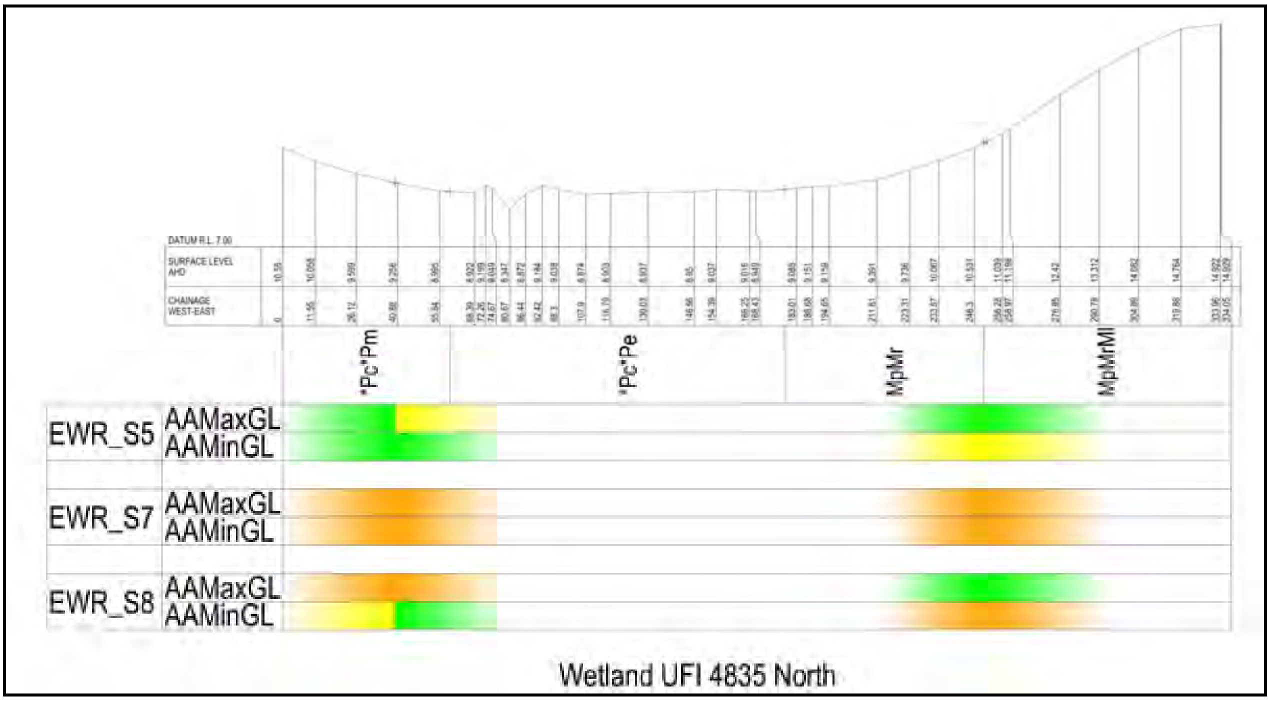


Figure 22 Airfield North wetland risk of impact mapping for climate change scenarios

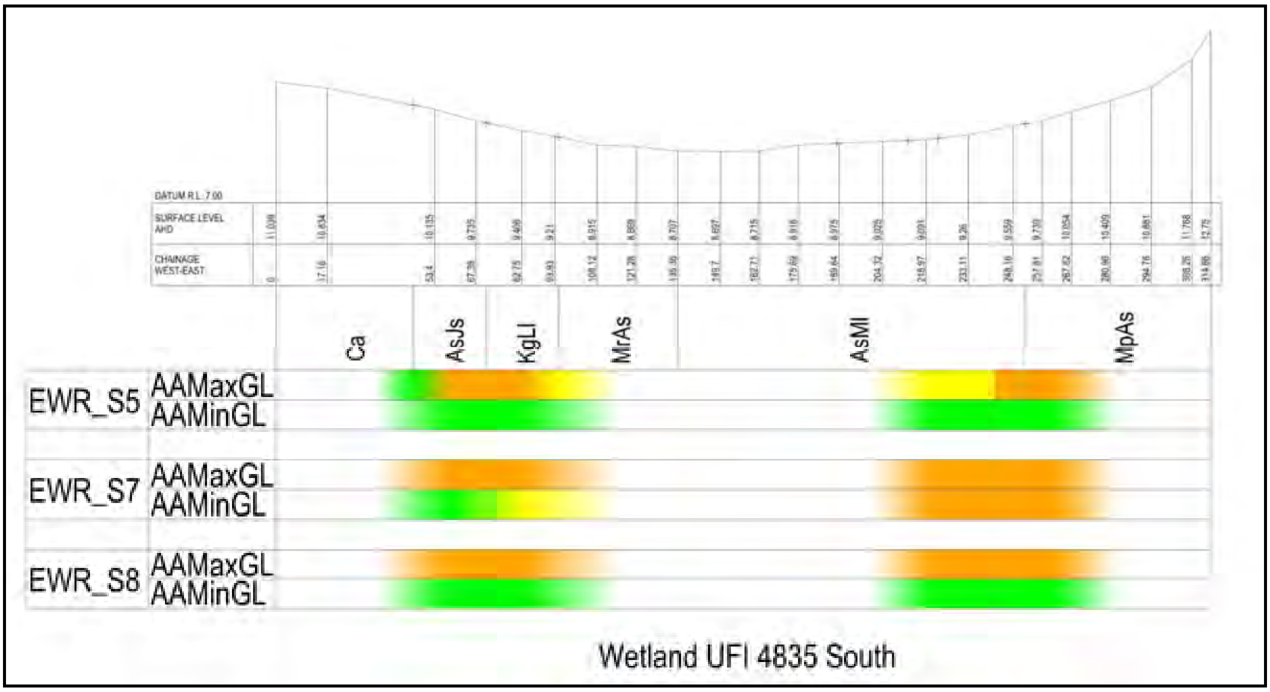


Figure 23 Airfield South wetland risk of impact mapping for climate change scenarios

9. Wetland UFI 5032 (Greyhound Road)

Greyhound Road Wetland (wetland UFI 5032 in the DEC geomorphic wetlands database) is located north of Greyhound Road, immediately north east of Lakes Road Wetland. The wetland is located on private property, is heavily vegetated and seasonally inundated, being dry during summer months.

The wetland receives surface water inflows through a drain entering the western edge of the wetland. There is a discharge drain to the south of the wetland (draining an area of approximately 1 km^2) which is likely to constrain the maximum water level in the wetland.

9.1 Background data

9.1.1 Previous studies

Local scale groundwater investigations indicate a tendency for regional groundwater to flow towards the south in this region (Parsons Brinkerhoff 2008; Bowman Bishaw Gorham 2006).

9.2 Site specific ecological data

The location of the ecological survey sites for Greyhound Road wetland are shown in Figure 24.

9.2.1 Vegetation and flora survey

The vegetation community types surveyed along the vegetation transect are described in Table 51. The condition of native vegetation was Pristine (1). Only a small section of the wetland was rated Degraded (6), due to an unnatural drainage channel.

Table 51 Vegetation community types for Greyhound Road wetland

Vegetation community name	Vegetation community description	Elevation range (mAHD)	Rare and priority species
Xp Kg	Tall open scrub of *Xanthorrhorea preissii* and *Kunzea glabrescens* over closed heath of *Dasypogon bromeliifolius* and *Laxmannia ramosa* with *Hypolaena exsulca, Phlebocarya ciliata* and *Lyginia barbarta* sedgeland	17.25 – 17.90	*Stylidium striatum* (P4) *Stylidium glaucum* (P4) *Stylidium brunonianum* (P4)
Mp Kg	Low open forest of *Melaleuca preissiana* over open scrub *Kunzea glabrescens* and *Adenanthos meisneri* over heath of *Dasypogon bromeliifolius* and *Laxmannia ramosa* with *Hypolaena exsulca, Phlebocarya ciliata* and *Lyginia barbarta* sedgeland	16.50 – 17.25	*Stylidium striatum* (P4)
Kg Ha	Closed tall scrub of *Kunzea glabescens* over closed heath of *Hypocalymma angustifolium, Pericalymma ellipticum* var *ellipticum* and *Euchilopis linearis* over sedgeland with *Hypolaena exsulca* and *Carex inversa*	16.35 – 16.5	

Vegetation community name	Vegetation community description	Elevation range (mAHD)	Rare and priority species
Kg Ml	Tall open scrub with *Kunzea glabrescens* and open heath with *Melaleuca lateritia*, *Calothamnus lateralis* and *Astartea scorparia* over open sedgeland with *Leipdosperma pubisquameum* and *Meeboldinia scariosa*	16.35 – 16.10	
Ml Mb	Closed tall scrub of *Melaleuca lateritia, Melaleuca brevifolia* and *Astartea scoparia* over an open sedgeland of *Lepidosperma longitudinale* and *Meeboldina scariosa*	16.10 – 16.00	
Mp Bsp	Open woodland of *Melaleuca preissiana* and Banksia sp. and tall open shrubland of *Kunzea glabescens* and *Astartea scoparia* over closed low heath with *Hypocalymma angustifolium* and sedgeland with *Hypolaean exsulca*	16.00 – 16.25	
Kg	*Kunzea glabrescens* shrubland	16.25 – 16.75	*Stylidium striatum* (P4)
Bsp	Low open forest of Banksia spp.	16.75-16.65	

9.2.2 Native fish and amphibian survey

No native fish species were recorded. Four frog species were identified by their calls during the site specific survey. These were *Litoria adelaidensis, Crinia glauerti, C insignifera* and *C. georgiana*

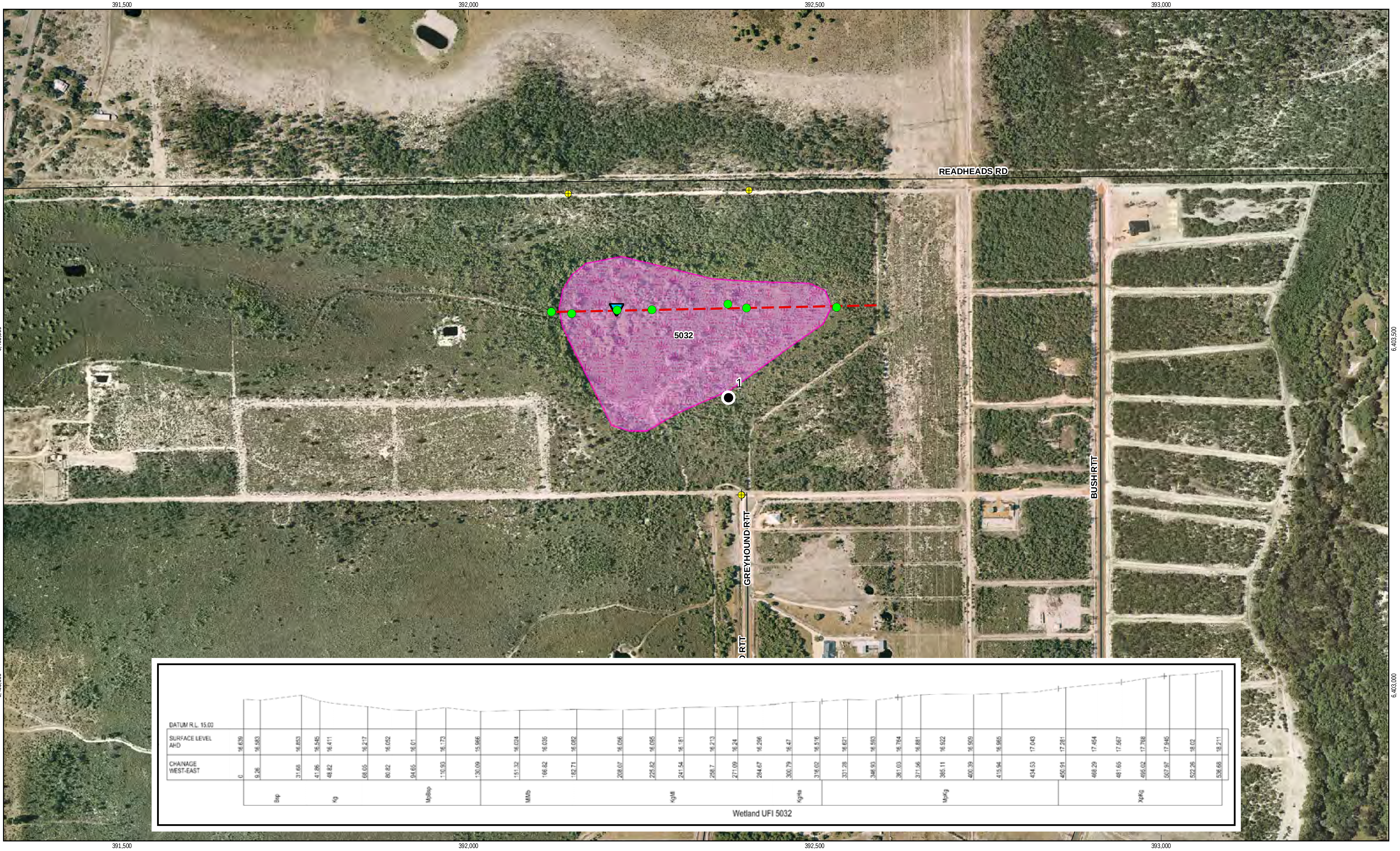
9.3 Ecological values and environmental objectives

The ecological values, conceptual environmental management objectives and operational (measurable) environmental management objectives are based on the desktop assessment and site specific ecological surveys (Table 52). The operational environmental objectives for the wetland are determined for the vegetative components of the wetland due to the relatively transient nature of faunal populations and the difficulties associated with monitoring other ecosystem processes such as sediment processes. The established vegetation transect will enable future monitoring to determine if the operational environmental management objectives are being met.

Table 52 Ecological values and environmental objectives of Greyhound Road wetland

Conservation significance	Ecological value	Site specific values	Environmental objective	Operational environmental management objective
State CCW DRF *Federal* EPBC Act	Wetland retains high ecological values Vegetation may contain conservation significant flora including rare and priority flora species Wetland ecosystem may contain habitat that	Vegetation condition *Pristine* Priority species: ◗ *Stylidium striatum* (P4) ◗ *Stylidium glaucum* (P4)	To maintain biodiversity To maintain hydrological functions Protect the habitat of significant	To maintain species composition To maintain species distribution To maintain species richness To control species

Conservation significance	Ecological value	Site specific values	Environmental objective	Operational environmental management objective
	supports significant fauna including threatened fauna and migratory bird species protected under the JAMBA and CAMBA agreements	◗ *Stylidium brunonianum* (P4) ◗ Carnaby's Black Cockatoo (*Calyptorhynchus latirostris*) opportunistically observed	fauna	mortality To maintain species condition and vigour To maintain community structure



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0 25 50 100 150 200 250

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

- Vegetation Type Boundary
- Frog and Fish Assessment Points
- Borehole
- mAHD Lowest Surveyed Point
- Approximate Transect Line
- Roads

Geomorphic Wetlands

- Conservation
- Resource Enhancement
- Multiple Use
- Not Assessed
- Not Applicable

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Department of Water
Murray Drainage and
Water Management Study

Job Number	61-2393704
Revision	A
Date	30 AUG 2010

Wetland UFI 5032
Greyhound Road Wetland

Figure 24

G:\61\2393706\GIS\mxds\612393704-G006_Figure 24 - Wetland UFI 5032 - Greyhound Road Wetland.mxd

GHD House, 239 Adelaide Terrace Perth WA 6004 **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Data Source: DEC: Geomorphic Wetlands, Swan Coastal Plain - 20070319; GHD: Approximate Transect Lines - 20090624; Landgate: Metro South 2009 Mosaic - 20090627; Landgate: Roads - 20090625; GHD: Vegetation Type Boundaries - 20100327, Frog and Fish Assessment Points - 20090821. Created by: kdiralu, jhchen

9.4 Description of water regime

9.4.1 Surface water

The surface water level within the Greyhound Road wetland displays a distinct seasonal fluctuation in response to climatic conditions and surface water levels in the Greyhound Road wetland show a markedly similar pattern on an annual basis. Figure 25 displays the modelled surface and groundwater levels for the Greyhound wetland at the lowest surveyed elevation point along the wetland transect.

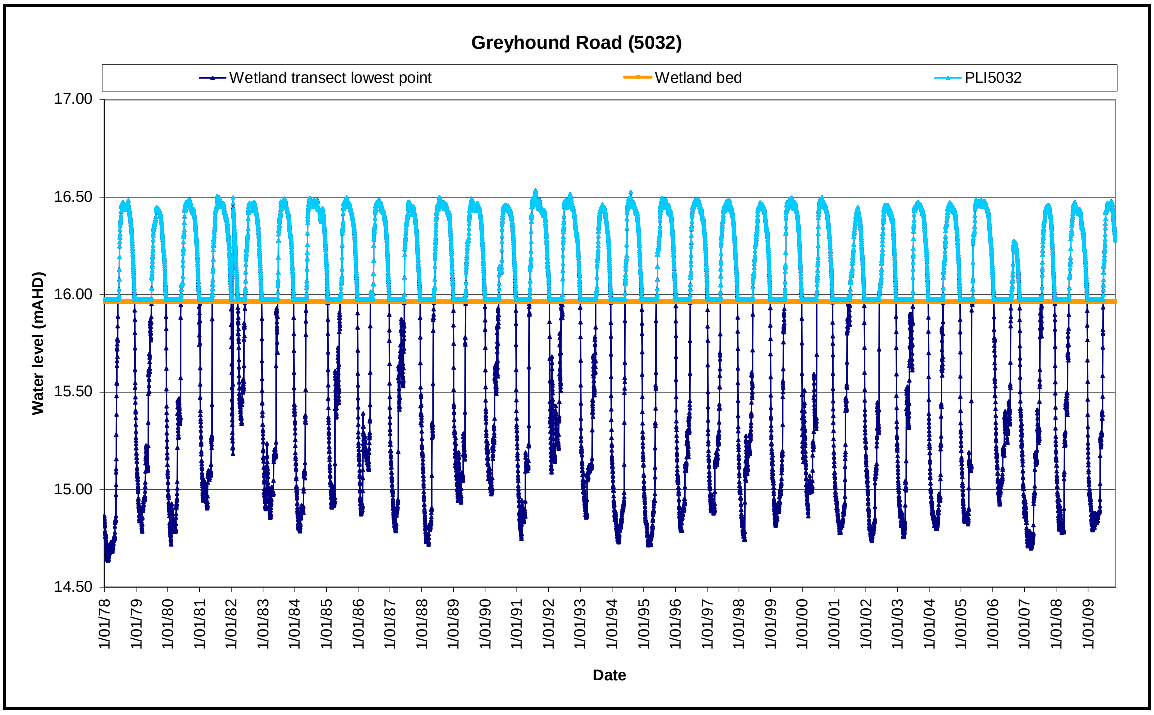


Figure 25 Modelled surface and ground water level in Greyhound Road wetland at the lowest point along the wetland transect

The minimum surface water level in Greyhound Road wetland is 15.97 mAHD, corresponding with the lowest surveyed elevation point along the wetland transect. The minimum and maximum surface water levels for the various periods are displayed in Table 53.

Table 53 Greyhound Road wetland modelled absolute and annual average minimum and maximum surface water level

Period	Minimum (mAHD)		Maximum (mAHD)	
	mAHD	mAGL	mAHD	mAGL
1978-2009	15.97	0.00	16.54	0.57
20 year annual average	15.97	0.00	16.47	0.50
10 year annual average	15.97	0.00	16.45	0.48

Period	Minimum (mAHD)		Maximum (mAHD)	
	mAHD	mAGL	mAHD	mAGL
5 year annual average	15.97	0.00	16.44	0.47
Timing	December-January		July-September	

9.4.2 Groundwater

Four bores were established at the Greyhound Road wetland with a bore to the north-west (HS109-1) a bore to the north (HS109-2) and a nest of two bores to the south of the wetland (HS108-2A and HS108-2B) (Figure 24). The minimum and maximum groundwater levels within the monitoring bores, and the general timing that these occur, are outlined in Table 54.

Table 54 Greyhound Road wetland modelled absolute and annual average minimum and maximum groundwater level

	HS108-2A		HS108-2B		HS109-1		HS109-2	
Minimum	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL
1978-2009	14.28	2.43	14.31	2.40	15.88	3.91	15.70	4.38
20 year annual average	14.50	2.21	14.52	2.19	16.19	3.60	16.03	4.05
10 year annual average	14.48	2.23	14.50	2.21	16.16	3.63	15.99	4.09
5 year annual average	14.47	2.24	14.49	2.22	16.14	3.65	15.98	4.10
Timing	April-June		April-June		April-May		April-June	
Maximum	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL
1978-2009	16.72	-0.01	16.49	0.22	18.66	1.13	18.67	1.41
20 year annual average	16.40	0.31	16.35	0.36	17.91	1.88	17.84	2.24
10 year annual average	16.27	0.44	16.26	0.45	17.71	2.08	17.62	2.46
5 year annual average	16.20	0.51	16.19	0.52	17.67	2.12	17.58	2.50
Timing	August-September		July-September		July-September		July-September	

9.4.3 Annual period of drying

Surface water data show that the Greyhound Road wetland dries on an annual basis (Table 55). The period of drying was calculated as the number of days of consecutive dry readings from the lowest surveyed point in the lake (i.e. no surface water in the lake). The summary statistics show that the Greyhound Road wetland has a historical maximum period of drying of 238 consecutive days in 2007 (approximately 8 months). When the whole period 1978-2009 is considered the wetland is historically dry for over 5 months in 50% of years. For the period 2000-2009 Greyhound Road wetland was dry for over 5.5 months in 50% of years.

Table 55 Greyhound Road wetland annual drying statistics

Annual drying statistics	1978-2009 (days)	2000-2009 (days)
Minimum	78	133
10th percentile	141	159
30th percentile	155	171
50th percentile	164	175
70th percentile	174	186
90th percentile	191	199
Maximum	238	238

9.4.4 Water level magnitude of change

The modelled magnitude of change (increase and decrease) in minimum and maximum water level for Greyhound Road wetland is displayed in Table 56. The magnitude of increase and decrease were similar for minimum water levels. The modelled maximum decrease in water level between years was higher for the maximum water levels.

Table 56 Greyhound Road wetland magnitude of change in annual minimum and maximum water levels

	Minimum levels	Maximum levels
Maximum increase (m/year)	0.34 (1991-1992)	0.18 (2006-2007)
Maximum decrease (m/year)	-0.33 (1982-1983)	-0.21 (2005-2006)

9.4.5 Water quality

9.4.5.1 Physiochemical parameters

TDS in Greyhound Road wetland ranged from between 307 mg/L (September 2009) and 434 mg/L (November 2009). The pH ranged between 3.80 (September 2009) and 4.16 (November 2009), which is the lowest pH range recorded for all wetlands in the Murray EWR study.

9.4.5.2 Nutrients

Total nitrogen and total phosphorus samples were collected and analysed for a single snapshot monitoring event in September 2009. Concentrations were reported as 2.6 mg/L for TN and 0.30 mg/L for TP.

9.5 Water requirements to maintain vegetation communities

The water requirements for selected vegetation communities at Greyhound Road wetland are summarised below. Figures displaying the water requirements of vulnerable species as well as the existing water levels at the upper and lower elevation extent of the vegetation communities are located in Appendix D.

9.5.1 Vegetation community KgMl

To maintain the most vulnerable species for vegetation community KgMl (*Calothamnus lateralis*) at a low level of risk a range in groundwater level of between 15.19 and 15.68 mAHD may be required based on the mean SW water level range for this species. The modelled minimum groundwater levels for the upper and lower elevation extents of the vegetation community are marginally below the mean minimum SW water levels (Most vulnerable U min and Most vulnerable L min), however are above the absolute minimum SW water levels (Most vulnerable U min ABS and Most vulnerable L min ABS) and therefore should meet the requirements of the most vulnerable species.

Based on the modelled water level data the vegetation community is inundated on an annual basis at both the lower elevation of 16.10 mAHD and upper elevation of 16.35 mAHD.

9.5.2 Vegetation community MpKg

To maintain the most vulnerable species for vegetation community XpKg (*Calothamnus lateralis*) at a low level of risk a range in groundwater level of between 15.34 and 16.43 mAHD may be required. The modelled minimum groundwater levels are considerably below mean minimum SW water levels at the upper leveation extent (Most vulnerable U min) and are marginally below the mean minimum SW water levels at thelower leveation extent (Most vulnerable L min). The modelled minimum water levels are similar to the absolute minimum SW water levels at the lower elevation extent of the vegetation community (Most vulnerable L min ABS) and therefore the water requirements of the most vulnerable species should be maintained at the lower elevation extent.

Based on the modelled water level data the vegetation community is frequently inundated on an annual basis at the lower elevation extent of 16.50 mAHD, and occasionally at the upper elevation extent of 17.25 mAHD.

9.5.3 Vegetation community XpKg

To maintain the most vulnerable species for vegetation community XpKg (*Pericalymma ellipticum*) at a low level of risk a range in groundwater level of between 16.03 and 17.62 mAHD may be required. The modelled groundwater levels for the upper and lower elevation extents of the vegetation community are below the mean minimum SW water levels for the vegetation community (Most vulnerable U min and Most vulnerable L min), however are similar to or above the absolute minimum SW water levels (Most vulnerable U min ABS and Most vulnerable L min ABS) and therefore should meet the requirements of the most vulnerable species.

Based on the modelled water level data the vegetation community is occassionally inundated at its lower elevation of 17.25 mAHD, and is not inundated at the upper elevation extent of 17.90 mAHD.

9.6 Interim ecological water requirement to maintain the environmental objectives

The EWRs to maintain the environmental objectives of Greyhound Road wetland are summarised in Table 57. The EWRs are of an interim nature and are based on the modelled wetland water regime. Comparison of the maximum and minimum water level values identify that the interim EWRs are able to meet the water requirements of the vegetation communities as described in Section 9.5. It is assumed that maintenance of the water regime of the vegetation communities will ensure other ecological objectives of the wetland are maintained.

Table 57 Interim ecological water requirements for Greyhound Road wetland

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	EWR	Limits of acceptable change
Maintain biodiversity of Greyhound Road wetland (Wetland UFI 5029)	Condition: Vegetation condition rated as *Pristine*, with small *Degraded* section. Trend: Trend in vegetation condition not identified as only single survey conducted.	**Groundwater level**			
		Maximum	HS109-1: 17.26 to 18.66 mAHD (17.71 mAHD) HS109-2: 17.06 to 18.67 mAHD (17.62 mAHD) HS108-2A: 15.39 to 16.72 mAHD (16.28 mAHD) HS108-2B: 15.37 to 16.49 mAHD (16.26 mAHD)	Timing: peak water levels generally between July and September	Limit unable to be set due to limited site specific data
		Minimum	HS109-1: 15.88 to 16.51 mAHD (16.16 mAHD) HS109-2: 15.70 to 16.36 mAHD (16.00 mAHD) HS108-2A: 14.28 to 14.76 mAHD (14.48 mAHD) HS108-2B: 14.31 to 14.77 mAHD (14.50 mAHD)	Timing: minimum water levels generally between April and June	
		Surface water level			
		Maximum	16.28 to 16.53 mAHD (16.45 mAHD) Maximum water level > 16.45 mAHD: Nine out of ten years	>16.45 mAHD in at least 9 out of 10 years Timing: peak water levels generally occur in July to September	Limit unable to be set due to limited site specific data
		Minimum	1978-2009: 15.96 mAHD (15.96 mAHD) *Note PLI set at 15.98 mAHD*	Timing: minimum water levels generally between December and January	

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	EWR	Limits of acceptable change
		Period of drying			
		Minimum	1978-2009: 78 days 2000-2009: 133 days	Wetland dries on an annual basis for period of between 78 and 238 consecutive days	Limit unable to be set due to limited site specific data
		Median	1978-2009: 164 days 2000-2009: 175 days		
		Maximum	238 consecutive days		
		Magnitude of change in water level			
		Maximum	Increase: 0.18 m/yr Decrease: 0.21 m/yr	Magnitude of change should not exceed historic levels. Peak levels should not occur in successive years. Water levels should not remain stable i.e. 0 m/yr magnitude of change in successive years.	Limit unable to be set due to limited site specific data
		Minimum	Increase: 0.34 m/yr Decrease: 0.33 m/yr		

9.7 Scenario assessment for Greyhound Road

9.7.1 Sand dune analysis (EWR_S1)

The Greyhound Road wetland has a significant dune (4 m high) to the north of the wetland. DoW WSB analysis of the change to wetland water regime based on the removal of the sand dunes identified a change to the average annual maximum wetland water level of 0.01 m corresponding to a 0.8% reduction in average maximum water level for Airfield South wetland (Hall *et al.* 2010c).

9.7.2 Hydrologic zone analysis (EWR_S2, EWR_S3 and EWR_S4)

The hydrologic zone analysis for Greyhound Road wetland revealed very small changes in average maximum wetland water level, with all drainage depth scenarios achieving < 10% change. This was attributed to the maximum wetland level being constrained by the depth of the drain that drains the wetland to the south (Hall *et al.* 2010c).

9.7.3 Climate scenarios (EWR_S5, EWR_S7 and EWR_S8)

The effect of climate change on the minimum and maximum water level depth for Greyhound Road wetland is displayed in Table 58.

9.7.3.1 Minimum water levels

The assessment of climate change scenarios on minimum water levels identified that the wet climate (EWR_S5) achieves a 3% decline in annual average minimum water level from the base case, while the historical wet climate (EWR_S8) scenario predicts a 6% increase. For the dry climate scenario (EWR_S7) the predicted change is a decline of 0.13 m (11% change).

9.7.3.2 Maximum water levels

The wet climate scenario (EWR_S5) predicts a 1% decline in annual average maximum water level from the base case, while the historical wet climate predicts a 6% increase in water level. For the dry climate (EWR_S7) the predicted change in maximum water level is 21%, a decline of 0.11 m.

Table 58 Change in Greyhound Road wetland water levels for wet, dry and historical wet climate change scenarios

Change in groundwater level compared to base case	S5		S7		S8	
	m	% change	m	% change	m	% change
AAMinGL	-0.03	3%	-0.13	11%	0.07	6%
AAMaxGL	-0.01	1%	-0.11	21%	0.01	1%

9.8 Risk of impact mapping

The risk of impact mapping for Greyhound Road wetland is displayed in Figure 26. The mapping shows that the risk of impact for AAmaxGL and AAminGL for scenarios S5 and S8 is predominantly low, with some high risk areas along the eastern edge of the wetland transect. The risk of impact is also predominantly low for AAminGL for scenario S7, with the western edge of the wetland transect mapped as moderate risk. The AAmaxGL for scenario S7 are mapped as high risk of impact.

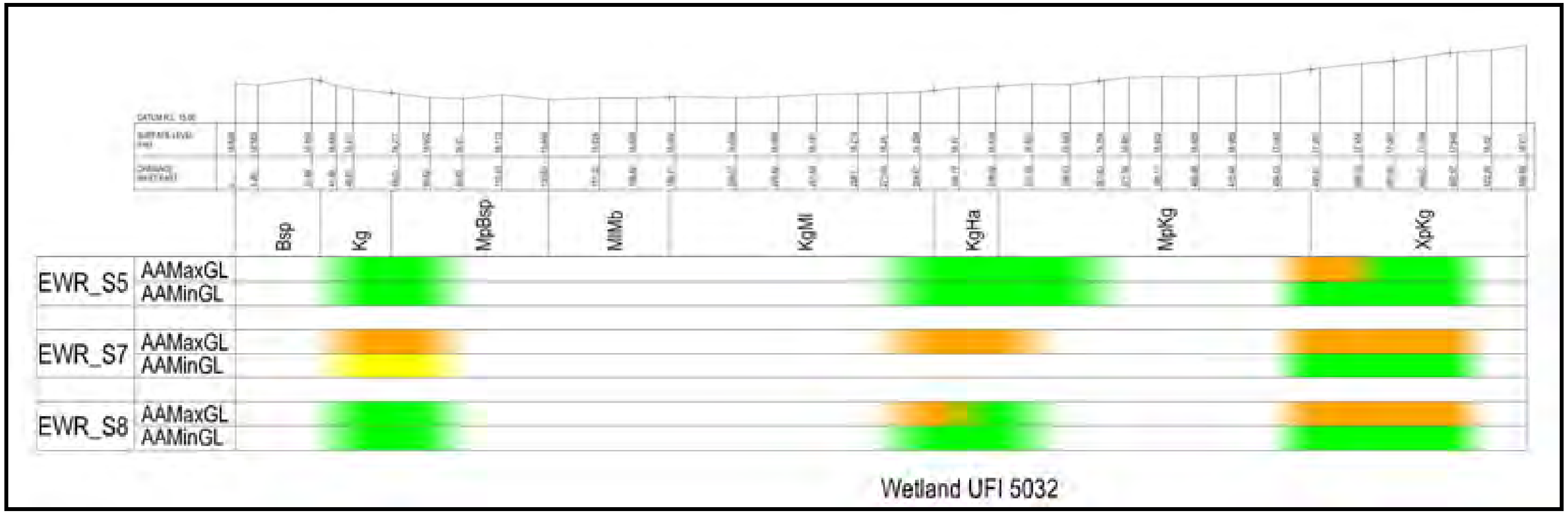


Figure 26 Greyhound Road wetland risk of impact mapping for climate change scenario

10. Wetland UFI 5056 (Phillips Road)

Phillips Road Wetland (wetland UFI 5056, 5055, 5195, 5196, 5198 and 5200 in the DEC Geomorphic Wetland Swan Coastal Plain dataset) is located in the south of the catchment, adjacent to the Pinjarra Golf Course, a caravan park, and the Pinjarra light industrial area. It is seasonally inundated in medium to high-rainfall years. The wetland appears to be highly disturbed, and is bisected by a high-voltage power line easement. The wetland is sparsely vegetated in parts, however it receives its conservation category rating due to the presence of a threatened ecological community (SCP9).

10.1 Background data

10.1.1 Previous studies

Local scale groundwater investigations indicate a tendency for regional groundwater to flow towards the south in this region (Parsons Brinkerhoff 2008; Bowman Bishaw Gorham 2006).

10.1.2 Threatened Ecological Communities

A search of the DEC's Threatened and Priority Ecological Communities database reveals that threatened ecological community SCP9 Herb rich shrublands in claypans occurs at Phillips Road wetland.

10.2 Site specific ecological data

The locations of the ecological survey sites for Phillips Road wetland are shown in Figure 27.

10.2.1 Vegetation and flora survey

The native vegetation condition ranged between Very Good (3) to Completely Degraded (6). The wetland was rated as Very Good to Good as weed species are present and some areas of the wetland have been burnt in the last 1 to 5 years. The boundaries of the wetland were rated as Good to Completely Degraded as these areas have been cleared and burnt recently and weed species are present.

Table 59 Vegetation community types for Phillips Road wetland

Vegetation community name	Vegetation community description[1]	Elevation range (mAHD)	Rare and priority species
Cc Mp	Open woodland of *Corymbia calophylla, Melaleuca preissiana , Xanthorrhoea preissii, Hypocalymma angustifolium* and mixed herbs	8.30-8.50	
Er Mp	Open woodland of *Eucalyptus rudis, Melaleuca preissiana* and *Melaleuca rhaphiophylla* over *Lepidosperma longitudinale* and weeds	8.00-8.30	
Cc Mp	Open woodland of *Corymbia calophylla, Melaleuca*	8.00-8.50	

[1] * Denotes introduced species

Vegetation community name	Vegetation community description[1]	Elevation range (mAHD)	Rare and priority species
	preissiana , *Xanthorrhoea preissii, Hypocalymma angustifolium* and mixed herbs		
Af Ap	Open woodland of *Allocasuarina fraseriana, Acacia pulchella* over mixed sedges and herbs	8.50-8.60	*Schoenus benthamii* (P3) *Stylidium brunonianum* (P4)
Cc Mp	Open woodland of *Corymbia calophylla, Melaleuca preissiana* , *Xanthorrhoea preissii, Hypocalymma angustifolium* and mixed herbs	8.60-8.70	*Schoenus benthamii* (P3) *Stylidium brunonianum* (P4)
Af Ap	Open woodland of *Allocasuarina fraseriana, Acacia pulchella* over mixed sedges and herbs	8.65-8.70	
Cc Mp	Open woodland of *Corymbia calophylla, Melaleuca preissiana* , *Xanthorrhoea preissii, Hypocalymma angustifolium* and mixed herbs	7.90-8.65	
Mp Ll	Open woodland of *Melaleuca preissiana* over *Lepidosperma longitudinale* and mixed herbs	7.90-8.00	*Schoenus benthamii* (P3)
Cc Mp	Open woodland of *Corymbia calophylla, Melaleuca preissiana* , *Xanthorrhoea preissii, Hypocalymma angustifolium* and mixed herbs	8.30-8.00	
*PW (VC01)	Paddock weeds	8.30-9.10	

10.2.2 Native fish and amphibian survey

No native fish species were recorded. Four frog species were identified by their calls during the site specific survey. These were *Litoria adelaidensis, Crinia glauerti, C. insignifera* and *Pseudophyne guentheri.*

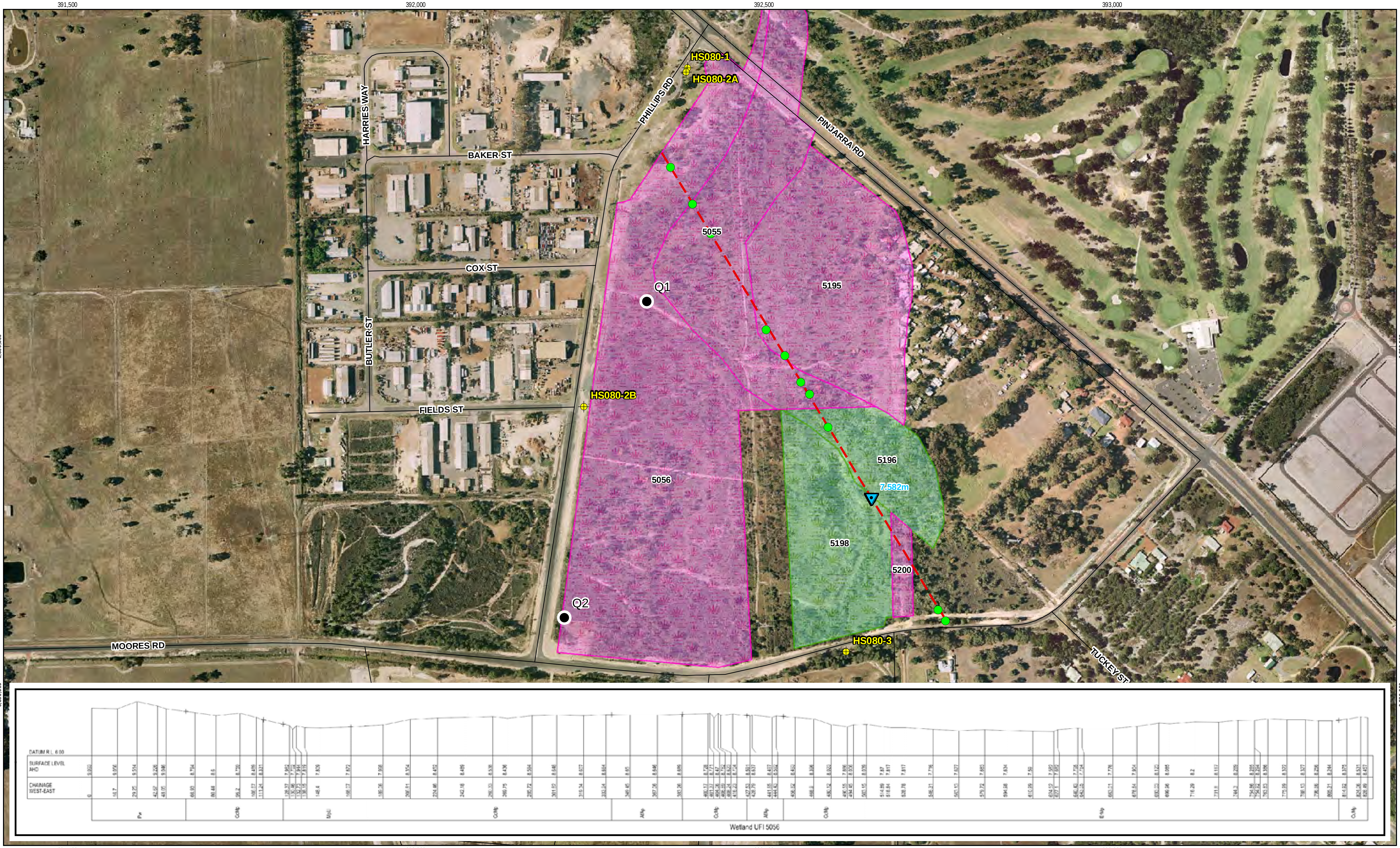
10.3 Ecological values and environmental objectives

The ecological values, conceptual environmental management objectives and operational (measurable) environmental management objectives are based on the desktop assessment and site specific ecological surveys (Table 60). The operational environmental objectives for the wetland are determined for the vegetative components of the wetland due to the relatively transient nature of faunal populations and the difficulties associated with monitoring other ecosystem processes such as sediment processes. The established vegetation transect will enable future monitoring to determine if the operational environmental management objectives are being met.

Table 60 Ecological values and environmental objectives of Phillips Road wetland

Conservation significance	Ecological value	Site specific values	Environmental objective	Operational environmental management objective
State	Wetland retains high	Vegetation	To maintain	To maintain species

Conservation significance	Ecological value	Site specific values	Environmental objective	Operational environmental management objective
CCW DRF TEC *Federal* EPBC Act	ecological values Vegetation may contain conservation significant flora including rare and priority flora species Wetland ecosystem may contain habitat that supports significant fauna including threatened fauna and migratory bird species protected under the JAMBA and CAMBA agreements	condition *Very Good* to *Completely Degraded* Priority species: ◗ *Schoenus benthamii* (P3) ◗ *Stylidium brunonianum* (P4)	biodiversity To maintain hydrological functions Protect the habitat of significant fauna	composition To maintain species distribution To maintain species richness To control species mortality To maintain species condition and vigour To maintain community structure



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0 25 50 100 150 200 250
Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

- Vegetation Type Boundary
- Frog and Fish Assessment Points
- Borehole
- mAHD Lowest Surveyed Point
- Approximate Transect Line
- Roads

Geomorphic Wetlands

- Conservation
- Resource Enhancement
- Multiple Use
- Not Assessed
- Not Applicable

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Department of Water
Murray Drainage and
Water Management Study

Wetland UFI 5056
Phillips Road Wetland

Job Number	61-2393704
Revision	A
Date	02 SEP 2010

Figure 27

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Data Source: DEC: Geomorphic Wetlands, Swan Coastal Plain - 20070319; GHD: Approximate Transect Lines - 20090624; Landgate: Metro South 2009 Mosaic - 20090627; Landgate: Roads - 20090625; GHD: Vegetation Type Boundaries - 20100327; GHD: Murray Wetland Boreholes - 20100119, Lowest Surveyed Points - 20100330, Frog and Fish Assessment Points - 20090821. Created by: kdiralu, jhchen

10.4 Description of water regime

10.4.1 Surface water

The surface water level within the Phillips Road wetland displays a distinct seasonal fluctuation in response to climatic conditions (Figure 28).

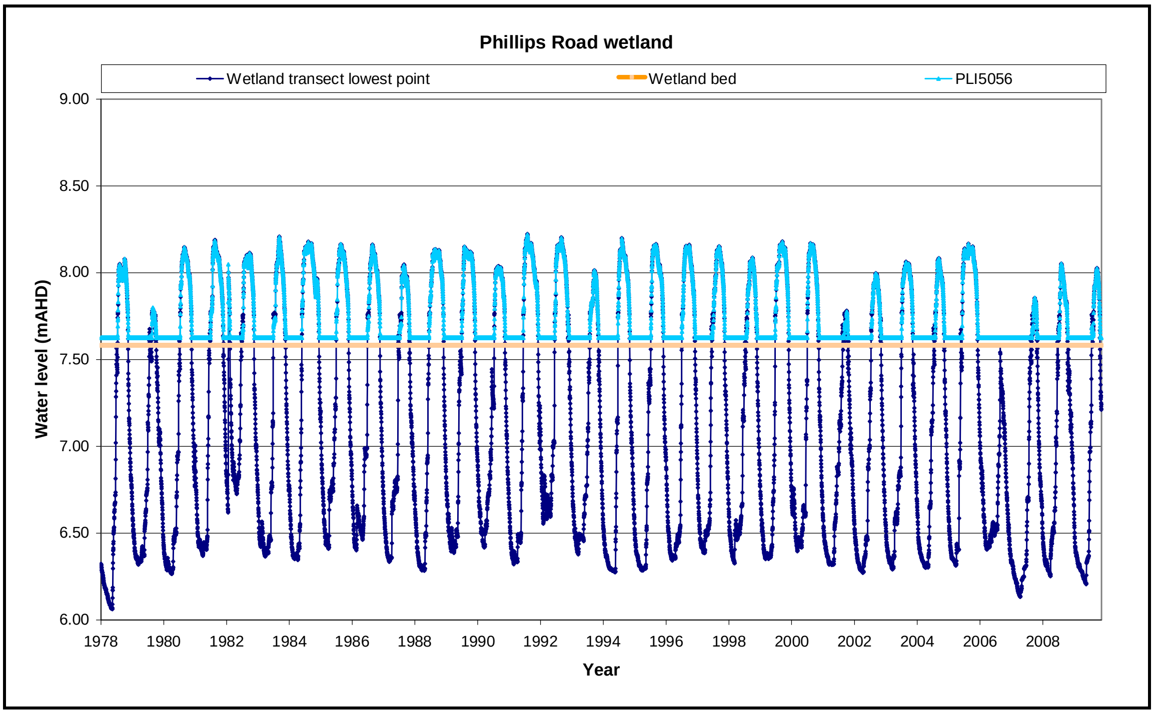

Figure 28 Modelled surface and ground water level in Phillips Road wetland at the lowest point along the wetland transect

The minimum surface water level in Phillips Road wetland is 7.58 mAHD corresponding with the lowest surveyed elevation point along the wetland transect. The mean annual minimum and maximum water levels for the various periods are displayed in Table 61.

Table 61 Phillips Road wetland modelled absolute and annual average minimum and maximum surface water level

Period	Minimum (mAHD)		Maximum (mAHD)	
	mAHD	mAGL	mAHD	mAGL
1978-2009	7.58	0.00	8.22	0.64
20 year annual average	7.58	0.00	8.06	0.48
10 year annual average	7.58	0.00	7.98	0.40
5 year annual average	7.58	0.00	7.94	0.36
Timing	February-May		August-October	

10.4.2 Groundwater

Four bores were established at Phillips Road wetland, a bore to north of the wetland (HS080-1), a nest of three bores to the west of the wetland (HS080-2A, HS080-2B and HS080-2C) and one bore south of the wetland (HS080-3) (Figure 27). The minimum and maximum groundwater levels within the monitoring bores, and the general timing that these occur, are outlined in Table 62.

Table 62 Phillips Road wetland modelled absolute and annual average minimum and maximum groundwater level

	HS080-1		HS080-2B		HS080-2C		HS080-3	
Minimum	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL
1978-2009	5.43	3.56	5.85	2.05	5.86	2.02	6.26	2.37
20 year annual average	5.93	3.06	6.11	1.79	6.11	1.77	6.52	2.11
10 year annual average	5.84	3.15	6.06	1.84	6.07	1.81	6.47	2.16
5 year annual average	5.77	3.22	6.05	1.85	6.05	1.83	6.45	2.18
Timing	March-May		March-May		March-May		March-May	
Maximum	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL	mAHD	mBGL
1978-2009	8.53	0.46	8.19	-0.29	8.18	-0.30	8.42	0.21
20 year annual average	7.96	1.03	7.95	-0.05	7.99	-0.11	8.13	0.50
10 year annual average	7.72	1.27	7.83	0.07	7.88	0.00	8.03	0.60
5 year annual average	7.60	1.39	7.75	0.15	7.79	0.09	7.96	0.67
Timing	August-September		August-September		August-September		August-September	

10.4.3 Annual period of drying

Surface water data show that the Phillips Road wetland dries on an annual basis (Table 63). As the Phillips Road wetland is a palusplain wetland the wetland may be dry for periods exceeding one or more years. The summary statistics show that the Phillips Road wetland has a historical maximum period of drying of 614 consecutive days from December 2005 to August 2007 (over 1.5 years). When the whole period 1978-2009 is considered the wetland is historically dry for over 7 months in 50% of years. For the period 2000-2009 Phillips Road wetland was dry for approximately 8 months in 50% of years.

Table 63 Phillips Road wetland annual drying statistics

Annual drying statistics	1978-2009 (days)	2000-2009 (days)
Minimum	126	191
10th percentile	189	214
30th percentile	211	236
50th percentile	223	245

Annual drying statistics	1978-2009 (days)	2000-2009 (days)
70th percentile	239	266
90th percentile	267	289
Maximum	365	365

10.4.4 Water level magnitude of change

The modelled magnitude of change (increase and decrease) in minimum and maximum water level for Phillips Road wetland is displayed in Table 64. The maximum increase and decrease in maximum water levels are higher than for minimum water levels. For minimum water levels the magnitude of maximum increase or decrease was equivalent.

Table 64 Phillips Road wetland magnitude of change in annual minimum and maximum water levels

	Minimum levels	Maximum levels
Maximum increase (m/year)	0.25 (1981-1982)	0.35 (1979-1980)
Maximum decrease (m/year)	-0.25 (1982-1983)	-0.58 (2005-2006)

10.4.5 Water quality

10.4.5.1 Physiochemical parameters

TDS in Phillips Road wetland ranged from between 153 mg/L (September 2009) and 1,708 mg/L (December 2009). The pH ranged between 6.06 (December 2009) and 7.45 (August 2009).

10.4.5.2 Nutrients

Total nitrogen and total phosphorus samples were collected and analysed for a single snapshot monitoring event in September 2009. Concentrations were reported as 1.6 mg/L for TN and 0.42 mg/L for TP.

10.5 Water requirements to maintain vegetation communities

The water requirements for selected vegetation communities at Phillips Road wetland are summarised below. Figures displaying the water requirements of vulnerable species as well as the existing water levels at the upper and lower elevation extent of the vegetation communities are located in Appendix D.

10.5.1 Vegetation community MpLl

To maintain the most vulnerable species for vegetation community MpLl (*Calothamnus lateralis*) at a low level of risk a range in groundwater level of between 6.74 and 7.18 mAHD may be required based on the mean SW water level range for this species. Modelled minimum groundwater levels typically range between 5.75 and 6.25 mAHD which is below the mean minimum SW water levels (Most vulnerable U min and Most vulnerable L min) for the upper and lower elevation extents, and below the the absolute minimum SW water levels for the upper and lower elevation extents (Most vulnerable U min ABS and

Most vulnerable L min ABS). The minimum water levels of the most vulnerable species may not be met by the modelled water regime.

Based on the modelled water level data the vegetation community is frequently inundated at its lower elevation of 7.90 mAHD, and its upper elevation of 8.00 mAHD.

10.5.2 Vegetation community AfAp

To maintain the most vulnerable species for vegetation community AfAp (*Hypocalymma angustifolium*) at a low level of risk a range in groundwater level of between 6.14 and 7.69 mAHD may be required based on the mean SW water level range for this species. The modelled minimum groundwater levels for the upper and lower elevation extents of the vegetation community are above the mean minimum SW water levels at the upper and ower elevation extent for the vegetation community (Most vulnerable U min and Most vulnerable L min) and therefore should meet the requirements of the most vulnerable species.

Based on the modelled water level data the vegetation community is occasionally inundated on an at its lower elevation of 8.65 mAHD, however is not inundated at its upper elevation of 8.70 mAHD.

10.5.3 Vegetation community CcMp

To maintain the most vulnerable species for vegetation community CcMp (*Juncus pallidus*) at a low level of risk a range in groundwater level of between 7.64 and 8.97mAHD may be required required based on the mean SW water level range for this species. Modelled minimum groundwater levels typically range between 6.05 and 6.45 mAHD which is below the mean minimum SW water levels (Most vulnerable U min and Most vulnerable L min) for the upper and lower elevation extents, and below the the absolute minimum SW water levels for the upper and lower elevation extents (Most vulnerable U min ABS and Most vulnerable L min ABS). The minimum water levels of the most vulnerable species may not be met by the modelled water regime.

Based on the modelled water level data the vegetation community is frequently inundated at its lower elevation of 8.00 mAHD, and is occasionally inundated at its upper elevation of 8.50 mAHD.

10.5.4 Vegetation community ErMp

To maintain the most vulnerable species for vegetation community ErMp (*Juncus pallidus*) at a low level of risk a range in groundwater level of between 7.64 and 8.77 mAHD may be required based on the mean SW water level range for this species. Modelled minimum groundwater levels typically range between 6.05 and 6.45 mAHD which is below the mean minimum SW water levels (Most vulnerable U min and Most vulnerable L min) for the upper and lower elevation extents, and below the the absolute minimum SW water levels for the upper and lower elevation extents (Most vulnerable U min ABS and Most vulnerable L min ABS). The minimum water levels of the most vulnerable species may not be met by the modelled water regime.

Based on the modelled water level data the vegetation community is frequently inundated at its lower elevation of 8.00 mAHD, however is not inundated at its upper elevation of 8.30 mAHD.

10.6 Interim ecological water requirement to maintain the environmental objectives

The EWRs to maintain the environmental objectives of Phillips Road wetland are summarised in Table 65. The EWRs are of an interim nature and are based on the modelled wetland water regime. Comparison of the maximum and minimum water level values identify that the interim EWRs are able to meet the water requirements of some of the vegetation communities as described in Section 10.5. However the modelled minimum water levels may not meet the minimum water requirements of the *most vulnerable species* for vegetation communities MpLl, CcMp and ErMp. It is assumed that maintenance of the water regime of the vegetation communities will ensure other ecological objectives of the wetland are maintained.

Table 65 Interim ecological water requirements for Phillips Road wetland

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	EWR	Limits of acceptable change
Maintain biodiversity of Greyhound Road wetland (Wetland UFI 5029)	Condition: Vegetation condition ranged from Very Good to Completely Degraded. Majority of wetland vegetation rated *Very Good* to *Good*.	**Groundwater level**			
		Maximum	HS080-1: 6.89 to 8.53 mAHD (7.72 mAHD) HS080-2B: 7.11 to 8.20 mAHD (7.83 mAHD) HS080-2C: 7.12 to 8.18 mAHD (7.88 mAHD) HS080-3: 7.44 to 8.42 mAHD (8.03 mAHD)	Timing: peak water levels generally between August and October	Limit unable to be set due to limited site specific data
	Trend: Trend in vegetation condition not identified as only single survey conducted.	Minimum	HS080-1: 5.44 to 6.44 mAHD (5.84 mAHD) HS080-2B: 5.85 to 6.46 mAHD (6.06 mAHD) HS080-2C: 5.86 to 6.45 mAHD (6.07 mAHD) HS080-3: 6.26 to 6.90 mAHD (6.47 mAHD)	Timing: minimum water levels generally between March and May	
		Surface water level			
		Maximum	7.58 to 8.22 mAHD	>8.15 mAHD in at least 2 out of	Limit unable to be set due to

Ecological objective	Baseline condition	Water regime component	Modelled range of natural variation (10 year annual average in brackets)	EWR	Limits of acceptable change
			(8.00 mAHD) Maximum water level > 8.15 mAHD: In at least 2 in 10 years	10 years Timing: peak water levels generally occur in August to October	limited site specific data
		Minimum	1978-2009: 7.58 mAHD (7.58 mAHD) *Note PLI set at 7.63 mAHD*	Timing: minimum water levels generally between February and May	
		Period of drying			
		Minimum	1978-2009: 126 days 2000-2009: 191 days	Wetland dries on an annual basis for period of 126 to 365 consecutive days	Limit unable to be set due to limited site specific data
		Median	1978-2009: 223 days 2000-2009: 245 days		
		Maximum	365 consecutive days		
		Magnitude of change in water level			
		Maximum	Increase: 0.35 m/yr Decrease: 0.58 m/yr	Magnitude of change should not exceed historic levels. Peak levels should not occur in successive years. Water levels should not remain stable i.e. 0 m/yr rate of change in successive years.	Limit unable to be set due to limited site specific data
		Minimum	Increase: 0.25 m/yr Decrease: 0.25 m/yr		

10.7 Scenario assessment for Phillips Road

10.7.1 Hydrologic zone analysis (EWR_S2, EWR_S3 and EWR_S4)

The hydrologic zone analysis identified that in order to achieve a change in average wetland water level of less than 10% a minimum extent of 200 m is sufficient for drainage at 0.5 m and at AAMaxGL. For drainage at 1mBGL the hydrologic zone extent was 500 m.

10.7.2 Climate scenarios (EWR_S5, EWR_S7 and EWR_S8)

The effect of climate change on the minimum and maximum water level depth for Phillips Road wetland is displayed in Table 66.

10.7.2.1 Minimum water levels

The assessment of climate change scenarios on minimum water levels identified that the wet climate (EWR_S5) achieves a 2% decline in annual average minimum water level from the base case, while the historical wet climate (EWR_S8) scenario predicts a 4% increase. For the dry climate scenario (EWR_S7) the predicted change is a decline of 0.15 m (12% change).

10.7.2.2 Maximum water levels

The wet climate scenario (EWR_S5) predicts a 5% decline in annual average maximum water level from the base case, while the historical wet climate predicts a 4% increase in water level. For the dry climate (EWR_S7) the predicted change in maximum water level is 70%, a decline of 0.35 m.

Table 66 Change in Phillips Road wetland water levels for wet, dry and historical wet climate change scenarios

Change in groundwater level compared to base case	S5		S7		S8	
	m	% change	m	% change	m	% change
AAMinGL	-0.02	2%	-0.15	12%	0.05	4%
AAMaxGL	-0.02	5%	-0.35	70%	0.06	11%

10.8 Risk of impact mapping

The risk of impact mapping for Phillips Road wetland is displayed in Figure 29. The mapping shows that the risk of impact AAminGL is low for scenarios S5 and S8, and varies between low and moderate for different vegetation change locations along the wetland transect. For AAmaxGL the risk of impact is mapped as high for scenarios S7 and S8, and varies between low along the western edge of the transect to moderate and high for other vegetation change locations along the transect.

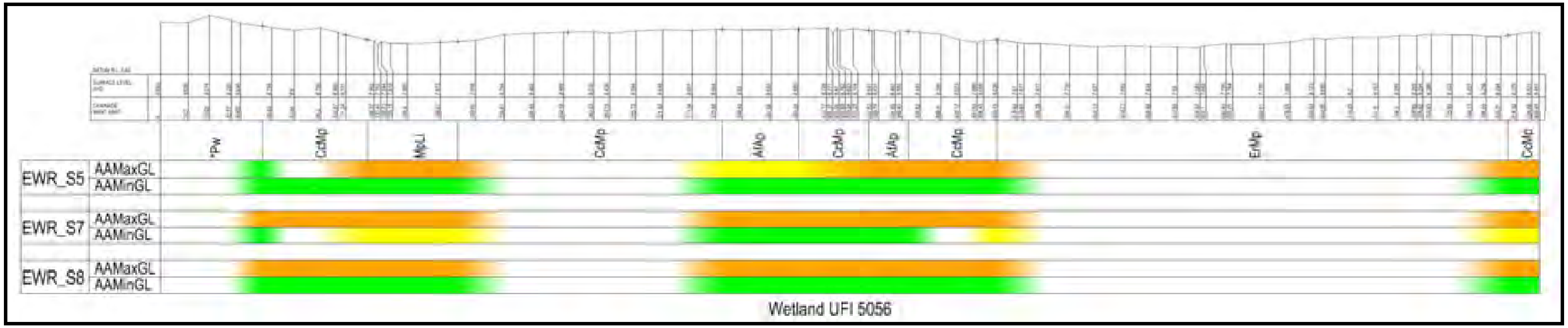

Figure 29 Phillips Road wetland risk of impact mapping for climate change scenario

11. Summary of Scenario Assessment

11.1 Sand dune analysis (EWR_S1)

The absolute and relative change in annual average maximum water levels was much lower for the Greyhound Road, Airfield North and Airfield South wetlands (<1.1% change compared to base case) when compared to the Scott and Benden Road wetlands (10.4 and 10.0 % decline in annual average maximum water levels respectively).

For Greyhound Road wetland the small predicted change in maximum water level with removal of sand dunes is attributed to water levels in the wetland being limited by the drainage depth. For the other wetlands the location of the sand dunes with regard to the direction of regional groundwater flow may influence the predicted impact on maximum water levels.

11.2 Hydrologic zone analysis (EWR_S2, EWR_S3 and EWR_S4)

For drainage set at AAMaxGL the hydrologic zone required for the different wetland sites varied between 100 m at Airfield North and 300 m for Airfield South wetland. Other wetlands, including Barragup Swamp, Benden Road, Scott Road and Phillips Road required a 200 m hydrologic zone. For Greyhound Road wetland the hydrologic zone scenario analysis predicted very small changes in water levels for all drainage depths, which was attributed to water levels being constrained by a an existing drain.

11.3 Climate scenarios (EWR_S5, EWR_S7 and EWR_S8)

The wet climate scenario (EWR_S5) predicts a smaller (a decline compared to base case) annual average minimum and maximum ground water levels compared to the base case scenario (EWR_S0) for all wetlands excluding Barragup Swamp. The dry climate scenario (EWR_S7) similarly predicts a smaller (a decline compared to base case) annual average minimum and maximum ground water levels compared to the base case scenario (EWR_S0) for all wetlands excluding Barragup Swamp.

Scenario EWR_S8 based on the historical wet climate, predicts an increase in the annual average minimum and maximum ground water levels compared to the base case at the majority of wetlands including Benden Road, Airfield North, Airfield South, Greyhound and Phillips Road. For Scott Road wetland scenario EWR_S8 suggests a decline in annual average minimum groundwater levels and an increase in annual average maximum water levels. For Barragup Swamp scenario EWR_S8 predicts the opposite with an increase in annual average minimum water levels and decline in annual average maximum water levels.

11.4 Sea level change scenario (EWR_S9)

The sea level change scenario was assessed for Barragup Swamp only and predicted an increase in both annual average minimum and maximum water levels. The predicted increase in minimum water levels was larger (136% change) compared to minimum levels (18%).

12. Monitoring and contingency plan

12.1 Objective

The purpose of the monitoring program for the selected Murray wetlands is to ensure that the ecological values are protected by achieving the environmental objectives. Specifically the monitoring program objectives are:

- To improve the understanding of the hydrology-ecology linkages of the wetland sites.
- To improve the baseline dataset.
- To refine the interim EWRs for the wetland sites.
- To act as an early warning system, with indicators that provide enough information to support and enable adaptive management of the individual sites.
- To identify limits of acceptable change for wetland water regime components and ecological values.

12.2 Regional-scale

12.2.1 Parameters

Parameters monitored (physical, chemical and biological) have been selected to improve the understanding of the relationship between, and to detect trends in, the hydrology-biology linkages of the wetlands sites.

12.2.1.1 Rainfall

Rainfall records should be monitored to provide information on monthly and annual average rainfall compared to long term averages.

12.2.1.2 Surface water level monitoring

Monitoring of surface water will be undertaken to provide further data to refine the interim EWRs developed within this report. Monitoring will also be undertaken in order to detect changes in pattern or trends away from natural variability.

Monitoring location

Surface water levels will be monitored at the wetland Peak level indicator (PLI).

Monitoring frequency

Surface water levels will be monitored on a monthly basis when surface water is present.

12.2.1.3 Groundwater level monitoring

Monitoring of groundwater will be undertaken to provide further data to refine the interim EWRs developed within this report. Monitoring will also be undertaken in order to detect changes in pattern or trends away from natural variability.

Monitoring location

Groundwater levels will be monitored in the groundwater monitoring bores established for the Murray wetland sites.

Monitoring frequency

Groundwater levels will be monitored on a monthly basis.

12.2.1.4 Surface water quality

Monitoring location

Surface water quality samples should be undertaken from a designated location for each wetland. Sampling locations should be sited adjacent to the wetland PLI where possible or in a location decided in consultation with the Drainage and Waterways Branch of the DoW.

Monitoring frequency

Surface water quality will be monitored on a bi-monthly basis when surface water is present in the wetlands.

Parameters

Physiochemical parameters should be monitored *insitu* when surface water is present in the wetlands.

Two water sampling events will be conducted when surface water is present in the wetland (September and November) and analysed in a NATA accredited laboratory for the following:

- pH, Electrical Conductivity (EC), Total Suspended Solids; and
- Nutrients (Total Nitrogen, Total Phosphorous).

A single snapshot monitoring event of a suite of water quality parameters, including major anions and cations, heavy metals and nutrients, was undertaken in 2009 to characterise baseline water quality.

12.2.1.5 Groundwater quality

A single snapshot monitoring event of a suite of water quality parameters, including major anions and cations, heavy metals and nutrients, was undertaken in 2009 to characterise baseline water quality.

12.2.1.6 Vegetation monitoring

Vegetation monitoring should follow the methodology outlined in *Murray DWMP: Wetland vegetation and flora survey* (GHD in preparation). In summary these include:

- Mapping of vegetation community distribution along the selected transect.
- Monitoring of the vegetation community condition along the selected transect.
- Monitoring of vegetation quadrats for species diversity, species cover and abundance, vegetation structure.

Monitoring frequency

The changes to wetland conidition and composition along the wetland transects is likely to be a gradual response to external pressures including changes to the water regime (levels and quality) due to climate change or water management planning.

Monitoring of the vegetation community distribution and condition along the selected vegetation transects should occur on an annual basis in order to identify any changes from the baseline condition. A vegetation and flora survey of the selected vegetation transect should be undertaken on a biennial or triennial basis depending on the ecological values of the site.

12.2.2 Contingency plan

If water regime monitoring reveals that the monitored parameters occur outside of identified natural variation at any wetland site during the monitoring period this exceedance should be reported to the managing authority. Any further continued exceedance will trigger increased monitoring to detect underlying cause of changed conditions.

Following refinement of the interim EWRs the contingency plan should be triggered if monitoring reveals that monitored parameters exceed the identified limit of acceptable change.

12.2.3 Period of monitoring

The monitoring program described above should be implemented for a period of three years. Following this period the annual monitoring data should be compiled and reported and a review of interim EWRs undertaken.

12.3 Local-scale

At the local scale additional site specific monitoring will be required to revise the interim regional-scale EWRs to a level suitable for local and urban water management planning. Monitoring of other high value wetland sites located within or adjacent to proposed development areas at the local scale is also likely to be required in order to determine their EWRs.

The EWR monitoring requirements at the local scale will comprise similar parameters to the regional-scale EWR monitoring program, however the frequency of monitoring of some parameters is likely to increase. Guidance on the monitoring of EWR wetland sites should be sought from the Department of Environment and Conservation and DoW.

12.4 Sampling methods

12.4.1 Surface and groundwater monitoring

Sampling of surface and ground waters should follow Australian Standards AS/NZ 5667 series of Water quality sampling guidance notes.

A National Association of Testing Authorities accredited laboratory should perform water quality testing.

12.4.2 Vegetation monitoring

Spring flora surveys should be undertaken with reference to Guidance Statement 51, guidelines for *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia* (EPA 2004).

12.5 Data collation and analysis

Collated monitoring data should be entered into a database for the Murray wetland sites. The data should be checked against existing baseline data and QA/QC data should be checked, where relevant, to ensure the integrity of the data.

Data should also be checked to identify any outliers or trends away from natural variation that may trigger contingency actions.

12.6 Further recommendations

Contact and liaison with landowners and local land managers should be maintained in order to enable reporting of any disturbance activities.

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Appendix A

Glossary and shortened forms

Glossary

Biodiversity	Biological diversity or the variety of organisms, including species themselves, genetic diversity and the assemblages they form (communities and ecosystems). Sometimes includes the variety of ecological processes within those communities and ecosystems.
Conservation category wetland	Conservation category wetlands support a high level of ecological attributes and functions. These are the highest priority wetlands and the management objective is the preservation of wetland attributes and functions.
Conservation significance	An area of high conservation significance is a naturally vegetated or non-vegetated area including water bodies, bare ground and/or rock outcrops where conserving the environmental values of the area is important to meet the objective of the EP Act (EPA 2008).
Ecological water requirement	The water regime needed to maintain ecological values of water dependent ecosystems at a low level of risk (ARMCANZ and ANZECC 1996). A water regime is a prevailing pattern of water behaviour over a given time, components of which include depth, rate of rise and duration (Froend *et al.* 2004).
Ecosystem	The biota (plants, animals, fungi and microorganisms) occurring in a given area, along with the abiotic environment that sustains it (landform, soils, hydrology) and their interactions.
Environmental objective	An environmental goal or vision, arising from the need to protect or enhance environmental values, and which is quantified where practicable (EPA 2008).
Environmental values	The natural ecological processes occurring within water dependent ecosystems and the biodiversity of these systems.
Groundwater	Water that occupies the pores and crevices of rock or soil beneath the land surface.
Limit of acceptable change	The tolerance that is considered acceptable without indicating a change of 'ecological character' is occurring. Use of this concept requires good knowledge of natural variations, the boom-and-bust cycles than can occur naturally in these species or communities. Where this is lacking, the precautionary principle will be applied. (Department of Environment, Water, Heritage and the Arts, 2008)
Ramsar wetland	A wetland, or part of a wetland, designated by the Commonwealth under Article 2 of the Ramsar Convention for inclusion in the List of Wetlands of International Importance.
Resource enhancement wetland	Wetlands which may have been partially modified but still support substantial ecological attributes and functions. These are priority wetlands and the ultimate objective is to manage, restore and protect towards improving their conservation value.
Surface water	Water flowing or held in streams, rivers and other wetlands on the surface of the landscape.
Urban	Areas that are currently urban or where urban development is proposed (such as in planning documents including Region Schemes, Town Planning Schemes and Structure Plans). Includes greenfield and urban renewal projects where residential, commercial, industrial uses and rural residential uses are proposed, including in rural townsite areas.
Water dependent ecosystem	Those parts of the environment, the species composition and natural ecological processes of which are determined by permanent, seasonal or intermittent water or waterlogged soils, including flowing or standing water and water in groundwater aquifers, wetlands and waterways.
Wetland function area	The spatial boundary of the wetland. It normally would include the wetland itself, the wetland vegetation and any associated dependent terrestrial habitat (WAPC 2005).

Shortened Forms

AAMinGL	Annual average minimum groundwater level
AAMaxGL	Annual average maximum groundwater level
BF	Bush forever
CCW	Conservation Category wetland
DEC	Department of Environment and Conservation
DEWHA	Department of the Environment, Water, Heritage and Arts
DoW	Department of Water
DRF	Declared rare flora
DWMP	Drainage water management plan
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPP	Environmental protection policy
EWR	Ecological water requirement
GDE	Groundwater dependent ecosystem
mAGL	Metres above ground level
mAHD	Metres Australian Height Datum
mBGL	Metres below ground level
PLI	Peak level indicator
REW	Resource Enhancement wetland
TEC	Threatened ecological community
UFI	Unique feature identifier (Wetland number from DEC Geomorphic wetland database)
WDE	Water dependent ecosystem

Appendix B

Review of using vegetation water requirements for wetland EWRs

Background

Ideally wetland EWRs should consider the requirements of all ecological components in the ecosystem including fauna and sediments (Froend and Loomes 2004). However data relating to non-vegetative ecological components of a site are typically scarce in the absence of detailed investigations which typically results in the setting of EWRs based solely on wetland vegetation water requirements.

The approach of using vegetation EWRs as a surrogate for all components of an ecosystem is supported by available literature due to the importance of vegetative components in the provision of ecosystem services, as well as the ease of definition and measurement compared to more transient components.

These include Murray *et al.* (2003) who identify that adverse impacts to the vegetation and flora of an ecosystem generally result in changes to the associated fauna assemblages. Davis and Froend (1999) further identify that wetland plant communities comprise the basis of healthy wetland ecosystems without which the consequences may include:

- Direct loss of floral diversity;
- Reduced potential for plant recruitment
- Reduction in primary production;
- Subsequent loss of faunal diversity through loss of habitat and food;
- Decreased aeration of sediments;
- Increased nutrient levels as a consequence of reduced plant uptake;
- Elevated water temperatures and light levels in the littoral zone promoting algal blooms and subsequent deterioration in water quality.

Ensuring water regimes that protect habitat is important to maintain other biological aspects of the ecosystem and to ensure the maintenance of other ecological values and ecosystem processes of the wetlands. A review of literature relating to the ecological water requirements to maintain other key ecological values and processes was undertaken with information sourced from studies specific to wetlands on the Swan Coastal Plain where available. Much of the information relevant to the Swan Coastal Plain wetlands is derived from a study of the wetlands of the Gnangara and Jandakot Mounds by Froend *et al.* (2004). Key non-vegetative values and processes that were considered include:

- Fauna – including vertebrates, macroinvertebrates, stygofauna and waterbirds;
- Water quality; and
- Sediment processes.

Fauna

General

Fauna are generally identified as water dependent ecosystems due to their reliance on water in providing habitat, breeding sites and food (Froend et al. 2004). These factors are adequately maintained by the vegetative water requirements. However some fauna species, dominated by birds and larger mammals, rely on water not only for habitat provision but as a source of drinking water, while respiration provides many small mammals with their water requirements (SKM 2001).

Specific information regarding the water requirements of fauna species is generally limited, and the more transient nature of fauna species in many cases enables their migration between sites with more suitable water regime. The water requirements of mobile fauna do not necessarily involve the provision of permanently suitable habitat at a single wetland (Davis *et al*. 2001).

Froend *et al.* (2004) identify that faunal populations that are dependent on ecosystems at the lowest point in the landscape are likely to be most affected by water level decline as these ecosystems are unable to migrate downslope in the landscape in response to changes. Terrestrial fauna that are dependent on wetlands as a source of freshwater may become rare in areas where acute decline in surface water occurs.

Swan Coastal Plain

In their study of wetlands of the Gnangara and Jandakot Mounds Froend *et al.* (2004) identify that frogs generally require 4 months of surface water for breeding and long necked tortoises prefer up to 9 months of inundation. The water requirements for fish species was generally identified as permanent inundation, as the critical minimum threshold depth for survival of the majority of fish species was unknown. The exception for fishes was the Blackstripe Minnow, which was known to survive in seasonal wetlands while also requiring cool water during inundation periods. The water requirements specified by Froend *et al.* (2004) were identified as a high degree of soil moisture during summer to survive aestivation, and maintenance of adequate water depth during inundation periods to allow stratification to develop and so provide a cooler layer.

Huang (2009) identified that changes to reptile community species composition may result if habitat changes occur as changing habitats complement a different suite of life histories. Furthermore Valentine (2009) found that vegetation type was the strongest influence on the species richness, diversity and number of individual species in a study of the vertebrate fauna of the Gnangara Mound.

Macroinvertebrates

General

The water requirements of macroinvertebrates, as with other aquatic biota, typically relates to the presence of and quality of water, and alterations to the water regime.

Boulton (2003) examined the impact of drought on stream macroinvertebrate assemblages and noted that the impact on biota in different environments varies influenced by factors including antecedent hydrological conditions, the timing and severity of drying disturbance, and the presence of drought refuges. In wetlands where drying is a common event many macroinvertebrate species are known to have adaptations to drought periods which include the ability to aestivate (a dessication resistant stage enabling them to persist in moist sediments, beneath stones or in leaf litter) or have drought resistant stages (often as eggs or juveniles) which result in a rapid recovery following drought (Boutlon 1989). Macroinvertebrate species that are able to aestivate during drought periods have adaptations to protect populations against stop-start flows, but there is probably a considerable energy cost to re-entering torpor if flows cease again (Robson 2009).

Monitoring of macroinvertebrate family richness and community structure is generally described with regard to their seasonal response to water levels, water quality and habitat condition. Key methods for identifying macroinvertebrate family richness within Australian rivers and wetlands include the AUSRIVAS (Reynoldson 1997) and SIGNAL (Chessman 1995) methods. These methods monitor ecosystem health based on the macroinvertebrate assemblages present based on habitat type (AUSRIVAS) and water quality and habitat type (SIGNAL).

Swan Coastal Plain

The water requirements of Gnangara and Jandakot Mound macroinvertebrate assemblages have previously been described in a general sense by Froend *et al.* (2004) due to the lack of site specific information. They note that where macroinvertebrate richness of a wetland is significant the known temporal and spatial habitat heterogeneity may be maintained by ensuring maintenance of wetland vegetation assemblages. These general water requirements are described below.

Vegetation assemblages were identified by Froend *et al.* (2004) as a preferred surrogate for other site features and ecological processes that may influence macroinvertebrate richness on a wetland specific basis. The reasoning for this approach was that vegetation assemblages have the advantage of contributing to structural heterogeneity, being likely to reflect and contribute to all other influences, and being more likely to be mapped than sediments and water quality.

Where macroinvertebrate proportional endemism is significant for a wetland a specific understanding of the EWR's of the endemic speices or assemblages is required Froend *et al.* (2004). Where macroinvertebrate proportional rarity is significant for a wetland Froend *et al.* (2004) identify that the wetland/landscape geomorphology may be a sufficient surrogate since most proportional rarity is encountered in geomorphologically distinct wetlands likes springs, caves, etc.

For many of the wetlands of the Gnangara and Jandakot mounds Froend *et al.* (2004) identify that habitat diversity may be maintained by ensuring spring peak water levels inundate littoral sedges and fringing vegetation each year.

Waterbirds

General

Waterbirds collectively display feeding strategies that relate to morphological, behavioural and physiological factors as well as food availability (Hale and Butcher 2007). The feeding patterns of the waterbirds are largely driven by habitat resources, which are influenced primarily by climate, geomorphology and hydrological regime.

Swan Coastal Plain

An overview of the feeding habitats of the waterbirds of the Peel-Yalgorup Ramsar site was included in the ecological character description of the site by Hale and Butcher (2007). This included some of the waterbirds that may be present in the Murray region. The principal or commonly used habitats for feeding of some of the waterbird species that may be present within the Murray wetland sites are listed in the table below.

Species	Type of presence in Murray region	F1 Feed in dense inundated vegetation	F2 Shallows (<0.5m) and/or mud	F3 Deep water (>1m)	F4 Away from wetland habitats	F5 Saline water	F6 Fresh water
Haliaeetus leucogaster White-bellied Sea-Eagle	Species or species habitat likely to occur within area		X	X	X	X	X
Ardea alba Great Egret, White Egret	Breeding likely to occur within area		X		X	X	X
Ardea ibis Cattle Egret	Species or species habitat may occur within area		X		X		X

In discussing the water requirements of wetlands of the Gnangara and Jandakot mounds Froend et al. (2004) identify that high winter and/or spring peak levels are important to in some of the wetlands (Forrestdale Lake, Lake Joondalup) in order to prevent the spread of invasive vegetation across these wetlands in order to retain the open shallows on which the migratory waders depend in autumn and summer.

For other wetlands of the Gnangara and Jandakot mounds water permanence was identified as an important water regime feature for waterbirds in some wetlands (Loch McNess, Lake Nowergup, Lake Goolelal).

Stygofauna

General

Stygofauna populations are generally considered resilient to changing water levels due to their ability to migrate within the aquifer. A microcosm study by Tomlinson *et al.* (2007) identified that small bodied stygofauna are able to follow declining water levels, while larger bodied stygofauna may become stranded. However in general stygofauna populations are generally considered resilient to only the most extreme and rapid water level decline (T. Moulds *pers comm*.).

The greatest risk to stygofauna populations is presented by degradation of water quality within the aquifer. A review of the effect of Managed Aquifer Recharge on stygofauna populations identified that stygofauna response to salinity is likely to be species specific (Dillon *et al.* 2009). Stygofauna populations were found to occur across a wide dissolved oxygen range (Hancock and Boulton 2008), although the author of the Dillon *et al.* (2009) review noted some taxonomic groups were found less often in suboxic sites. The major water quality impact is noted to be organic loading, however this is unlikely to be an issue in the Murray DWMP Region.

Swan Coastal Plain

Decline in groundwater levels and water quality have also been found to be key threats to stygofaunal populations within the Gnangara region (Horwitz et al. 2009a).

Water Quality/sediments

General

Wetland water quality is often impacted by inflow of nutrients and pollutants, with wetlands generally acting as a site of nutrient accumulation within a catchment (Horwitz *et al.* 2009b). In-situ sediment processes also play an important role in wetland water quality with sediment type generally the determining factor for defining water regime requirements (Froend *et al.* 2004).

Increasing exposure of sediments due to drying may have a number of impacts including accumulation of organic matter, exposure of peat and organic materials to fire and exposure of potentially acid sulphate soils.

Swan Coastal Plain

The wetlands of much of the Swan Coastal Plain, including those within the Murray region, are generally hydraulically connected to the underlying superficial aquifer and therefore the wetland water quality largely reflects that of the underlying groundwater. Exceptions to this may be present where surface drainage flows directly into the wetland, or where a wetland is locally perched or disconnected from the superficial aquifer.

Froend *et al.* (2004) note that where *Baumea articulata* dominate a wetland system the species needs to be inundated each year in order to maintain water quality. The rationale given by Froend et al. (2004) for maintenance of water quality is that allochthonus organic matter is deposited faster than it can be broken down or washed away and accrues layers of peat. The EWRs for this objective are to ensure that sediments remain saturated/moist throughout summer to keep sediments anaerobic (to slow the metabolism) and prevent burning (since burning is very rapid metabolism).

For many of the wetlands of the Gnangara and Jandakot Mounds Froend *et al.* (2004) note that maintenance of water quality and sediment processes requires that sediments must remain saturated/moist throughout the summer each year, with the water table not dropping below the stratigraphic level/layer capable of providing water to surface organics through capillary rise during summer.

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(SKM) Sinclair Knight Merz (2001) *Environmental water requirements of groundwater dependent ecosystems, Environmental Flows Initiative Technical Report Number 1*, Commonwealth of Australia, Canberra.

Appendix C

Desktop database search results

Rare and Priority flora

Threatened Fauna

Rare and priority flora species of the Murray region

Species name	EPBC Act status	DRF database status	NatureMap	Murray wetlands[11]
Acacia benthamii			Priority 2	5056
Acacia lasiocarpa var. bracteolate long peduncle variant (G.J. Keighery 5026)			Priority 1	5032
Anthonium junciforme			Priority 4	5056
Caladenis speciosa			Priority 4	5032
Darwinia sp. Muchea (B.J.Keighery 2458) Muchea Bell	Critically Endangered	Species or species habitat likely to occur within area		
Dillwynia dillwynioides			Priority 3	3945 5056
Diuris purdiei Purdies Donkey Orchid			DRF	5056
Drakaea elastica Glossy-leaved Hammer-orchid, Praying Virgin	Endangered	Species or species habitat likely to occur within area		
Drakaea micrantha Hopper & A.P.Brown nom. inval. Dwarf Hammer-orchid	Vulnerable	Species or species habitat likely to occur within area		
Drosera occidentalis subsp *occidentalis*			Priority 4	5056
Grevillea bipinnatifida subsp *pagna*			Priority 2	3945
Lasiopetalum pterocarpum Wing-fruited Lasiopetalum	Endangered	Species or species habitat likely to occur within area		
Jacksonia sericea Waldjumi			Priority 4	3945
Johnsonia pubescens subsp. cygnorum, Keighery			Priority 2	4835 5032
Microtis quadrata			Priority 4	5056
Schoenus benthamii			Priority 3	5056
Schoenus pennisetis			Priority 1	5056
Stylidium longitubum Jumping Jacks			Priority 3	7046 5056
Synaphea sp. Fairbridge Farm (D.Papenfus 696) Selena's Synaphea	Critically Endangered	Species or species habitat known to occur within area		

[11] NatureMap search for individual wetlands was completed with a 1 km buffer around wetland as the searches were intended to be wetland specific

Species name	EPBC Act status	DRF database status	NatureMap	Murray wetlands[11]
Synaphea sp. Pinjarra (R.Davis 6578) Club-leafed Synaphea	Critically Endangered	Species or species habitat known to occur within area		
Synaphea stenoloba	Endangered	Species or species habitat known to occur within area	DRF	5056
Rhodanthe pyrethrum			Priority 3	5056
Triptococcus paniculatus			Priority 1	5056

Threatened fauna species of the Murray region

Species	EPBC Act status	Type of Presence	NatureMap	Murray wetlands[12]
Birds				
Calyptorhynchus banksii naso Forest Red-tailed Black-Cockatoo	Vulnerable	Species or species habitat may occur within area		
Calyptorhynchus baudinii Baudin's Black-Cockatoo, Long-billed Black-Cockatoo	Vulnerable	Species or species habitat likely to occur within area		
Calyptorhynchus latirostris Carnaby's Black-Cockatoo, Short-billed Black-Cockatoo	Endangered	Breeding likely to occur within area		
Numenius madagascariensis Eastern Curlew			Priority 4	3945
Migratory Birds				
Terrestrial Species				
Haliaeetus leucogaster White-bellied Sea-Eagle	Migratory	Species or species habitat likely to occur within area		
Merops ornatus Rainbow Bee-eater	Migratory	Species or species habitat may occur within area		
Wetland Species				
Ardea alba Great Egret, White Egret	Migratory	Breeding likely to occur within area		
Ardea ibis Cattle Egret	Migratory	Species or species habitat may occur within area		
Marine Birds				
Apus pacificus Fork-tailed Swift	Migratory	Species or species habitat may occur within area		
Ardea alba Great Egret, White Egret	Migratory	Breeding likely to occur within area		
Ardea ibis Cattle Egret	Migratory	Species or species habitat may occur within area		

[12] NatureMap search for individual wetlands

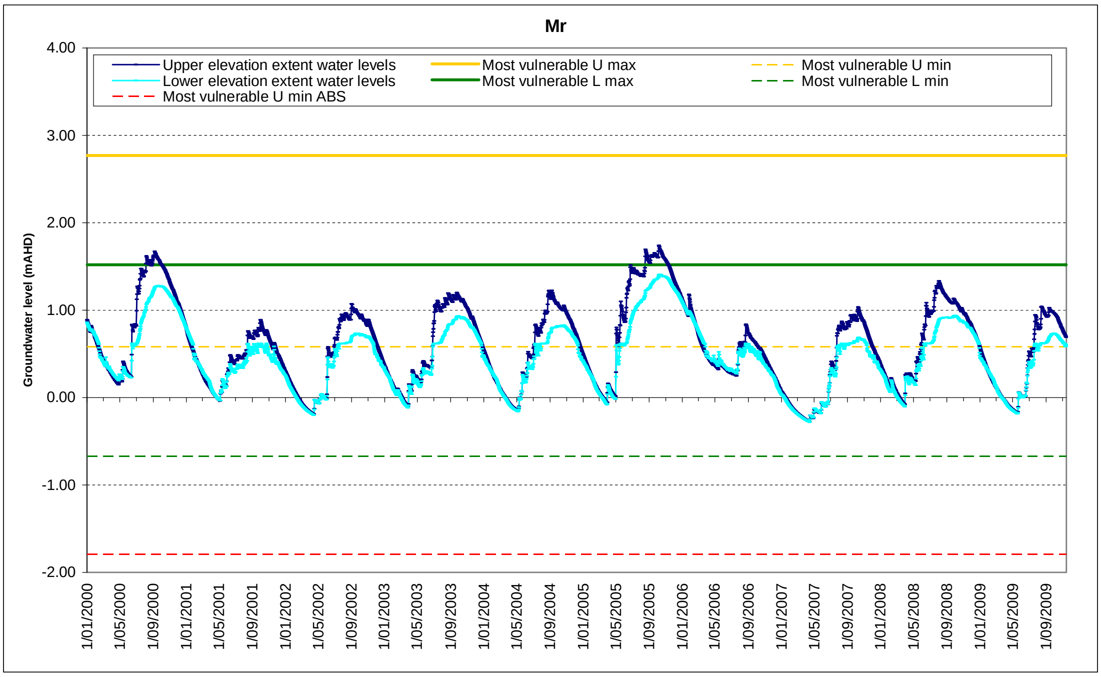
Species	EPBC Act status	Type of Presence	NatureMap	Murray wetlands[12]
Insects				
Synemon gratiosa Graceful Sun Moth	Endangered	Species or species habitat may occur within area		
Mammals				
Dasyurus geoffroii Chuditch, Western Quoll	Vulnerable	Species or species habitat likely to occur within area	T – rare or likely to become extinct	5180 5724 5032 3945
Hydrmys chrysogaster Water rat			Priority 4	3945
Myrmecobius fasciatus Numbat, Walpurti			T – rare or likely to become extinct	3945
Phascogale calura Red-tailed Phascogale	Endangered	Species or species habitat may occur within area		
Setonix brachyurus Quokka	Vulnerable	Species or species habitat may occur within area		
Isodon obesulus subsp. Fusciventer Southern Brown Bandicoot, Quenda			Priority 5	7046 3945

Appendix D

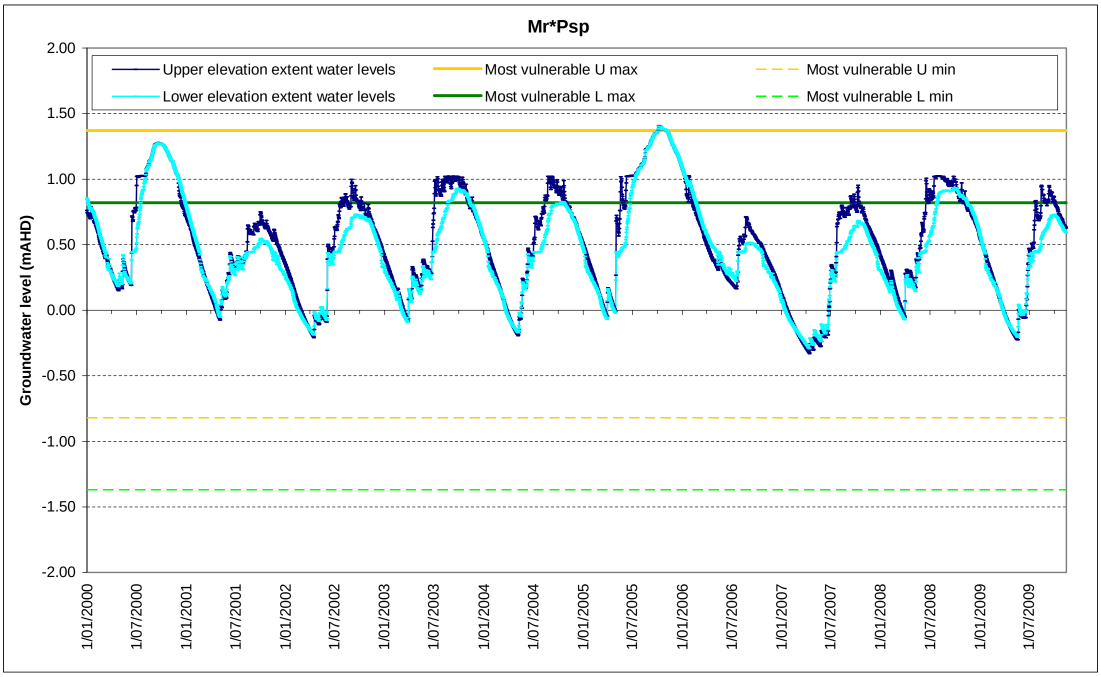
Wetland vegetation community water requirements

Barragup Swamp

Vegetation community Mr

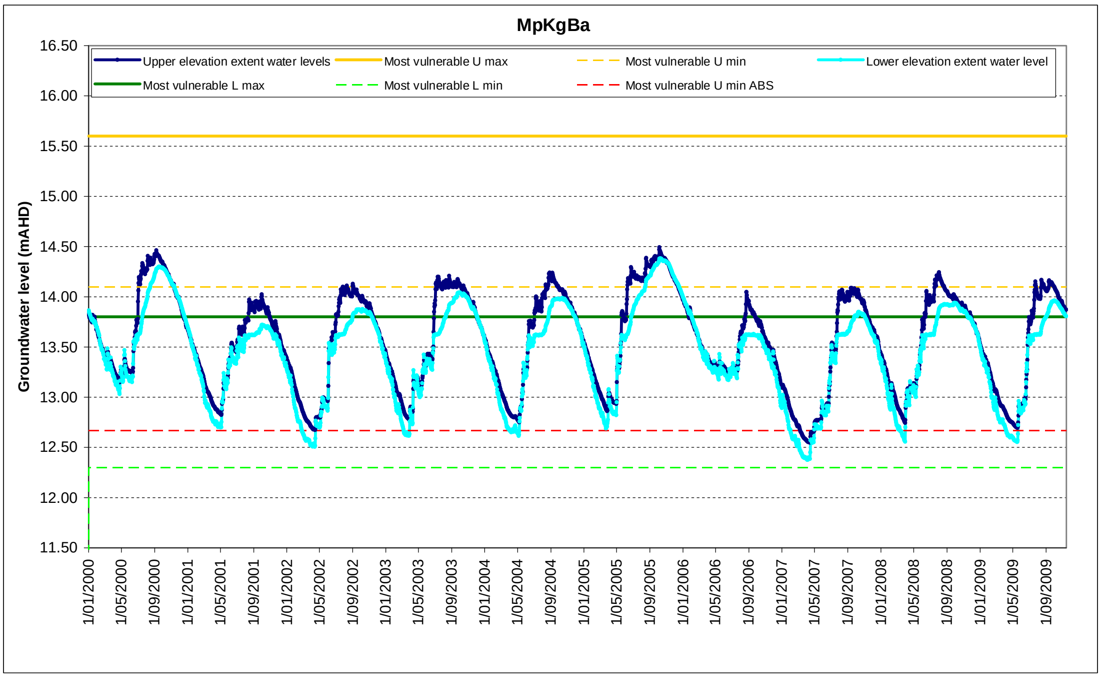


Vegetation community Mr*Psp

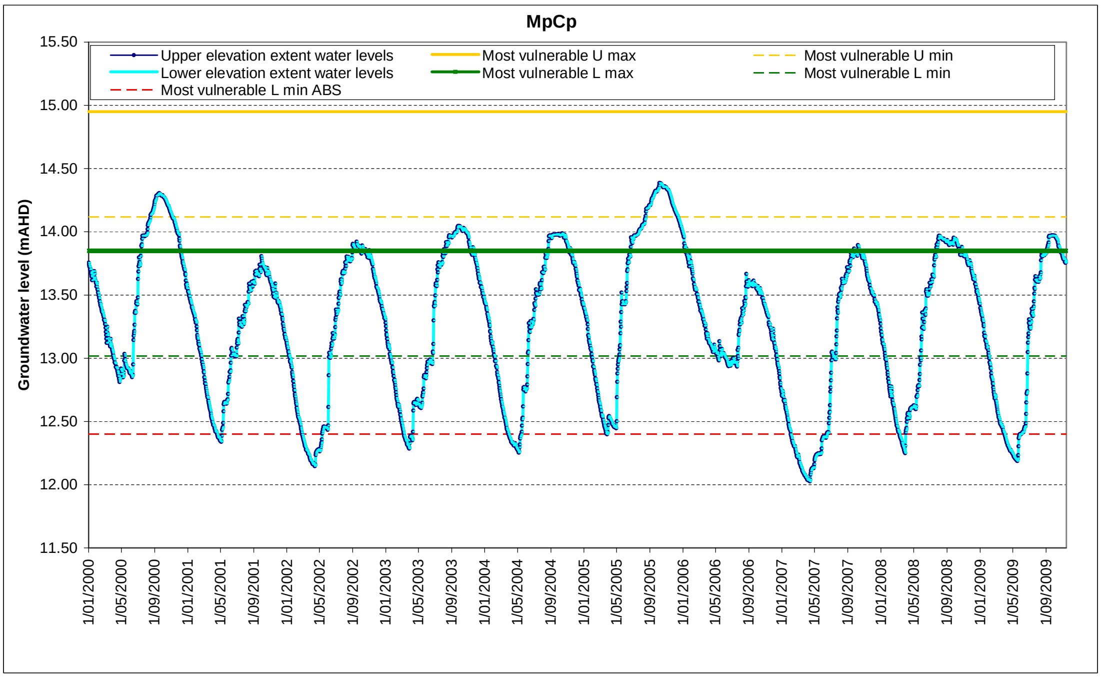


Benden Road wetland

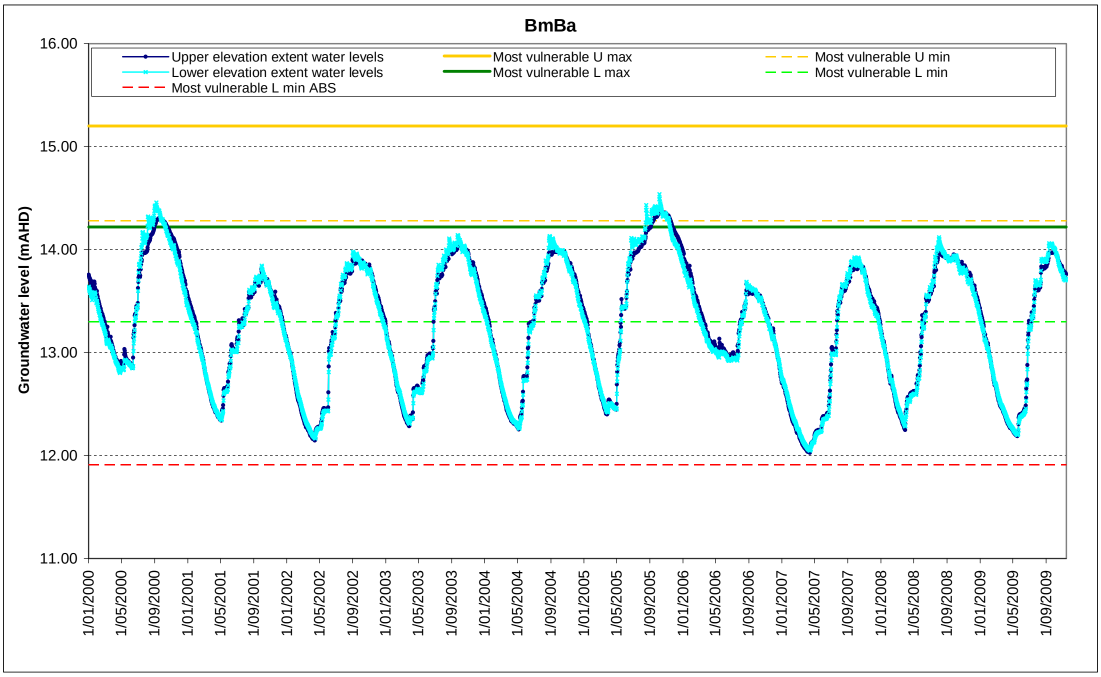
Vegetation community MpKgBa



Vegetation community MpCp

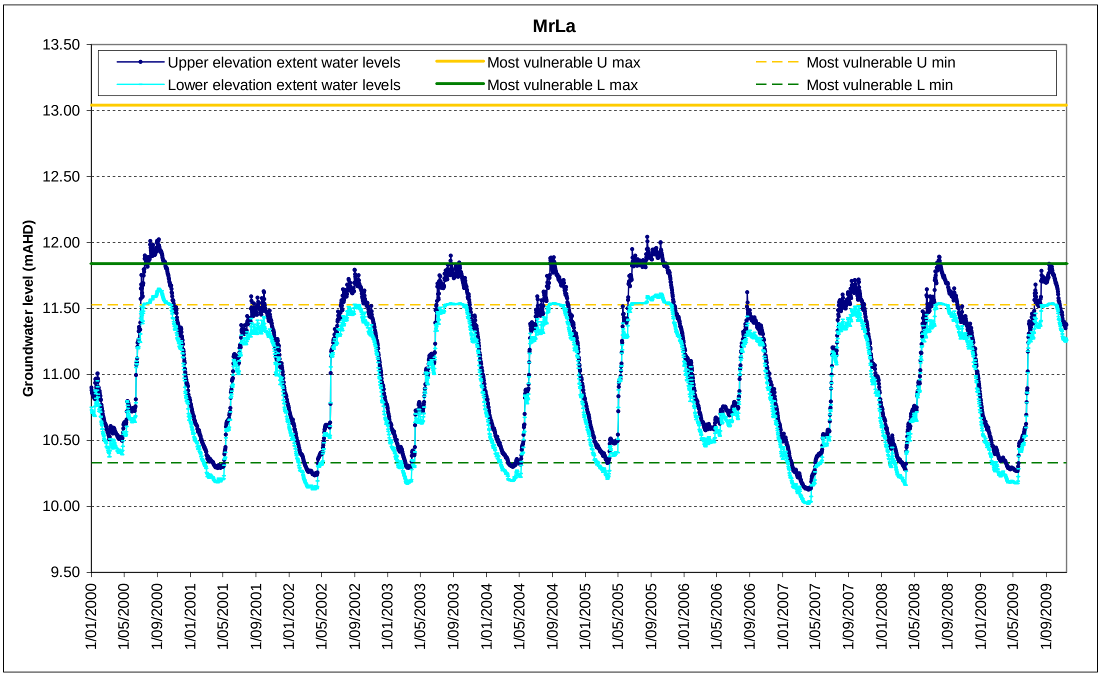


Vegetation community BmBa

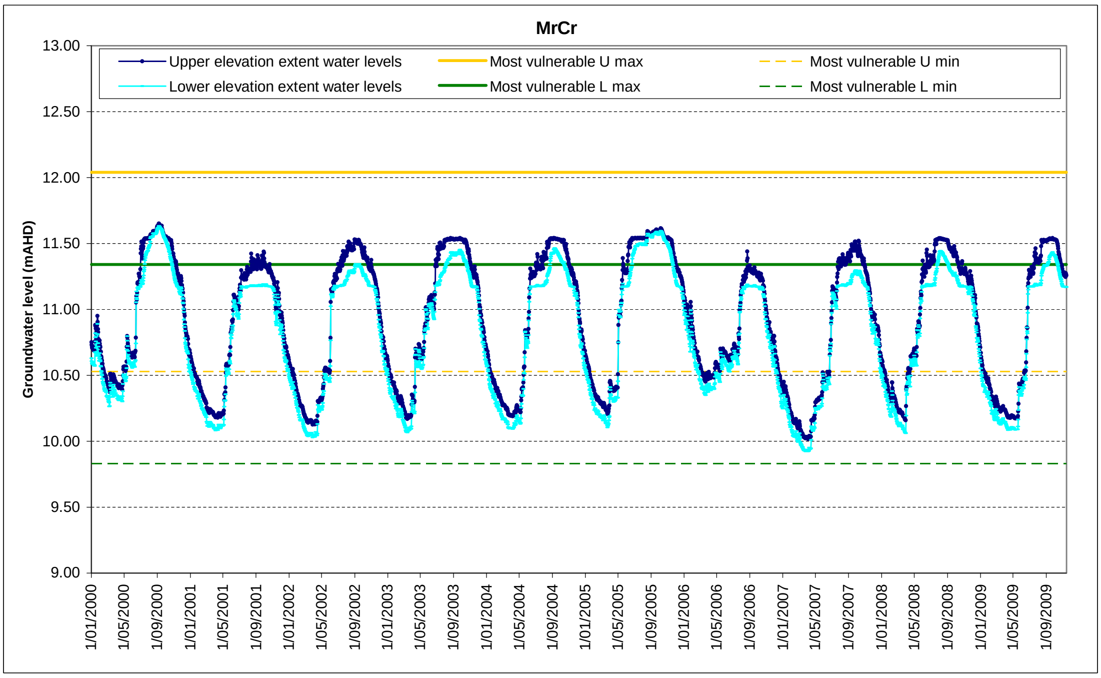


Scott Road wetland

Vegetation community MrLa

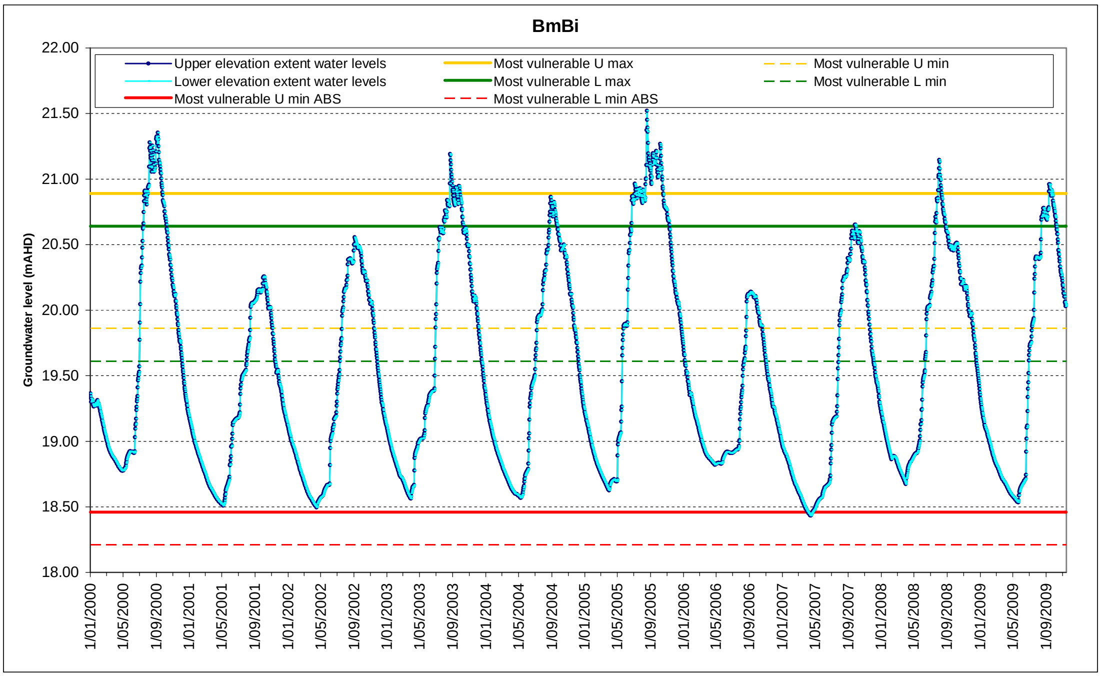


Vegetation community MrCr

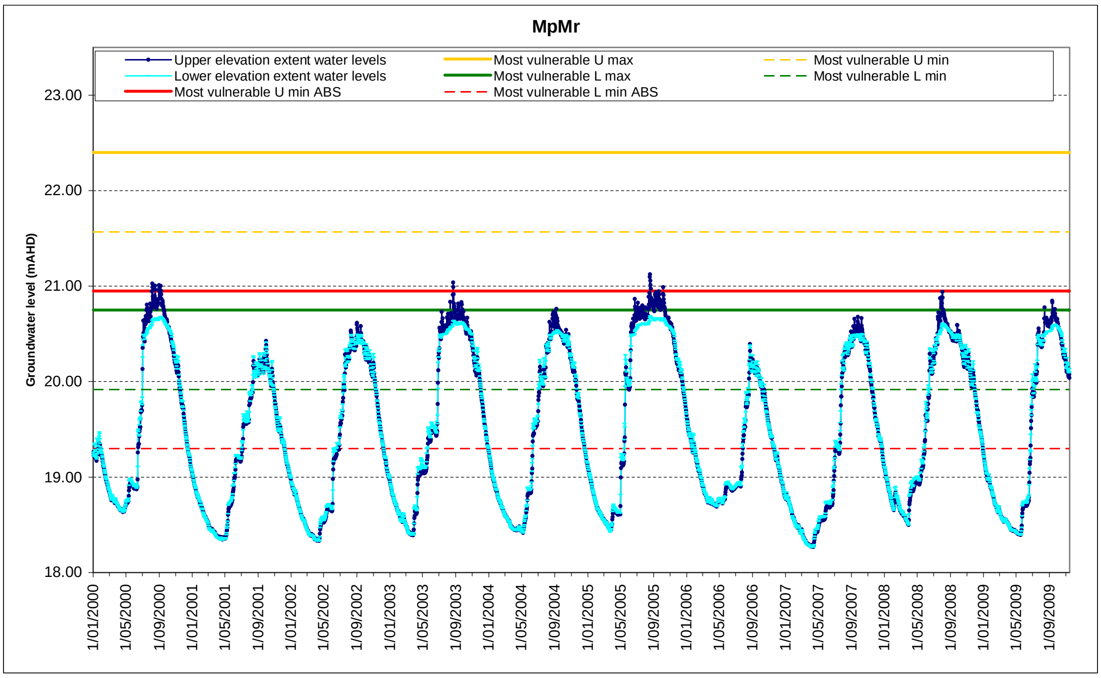


Elliott Road North wetland

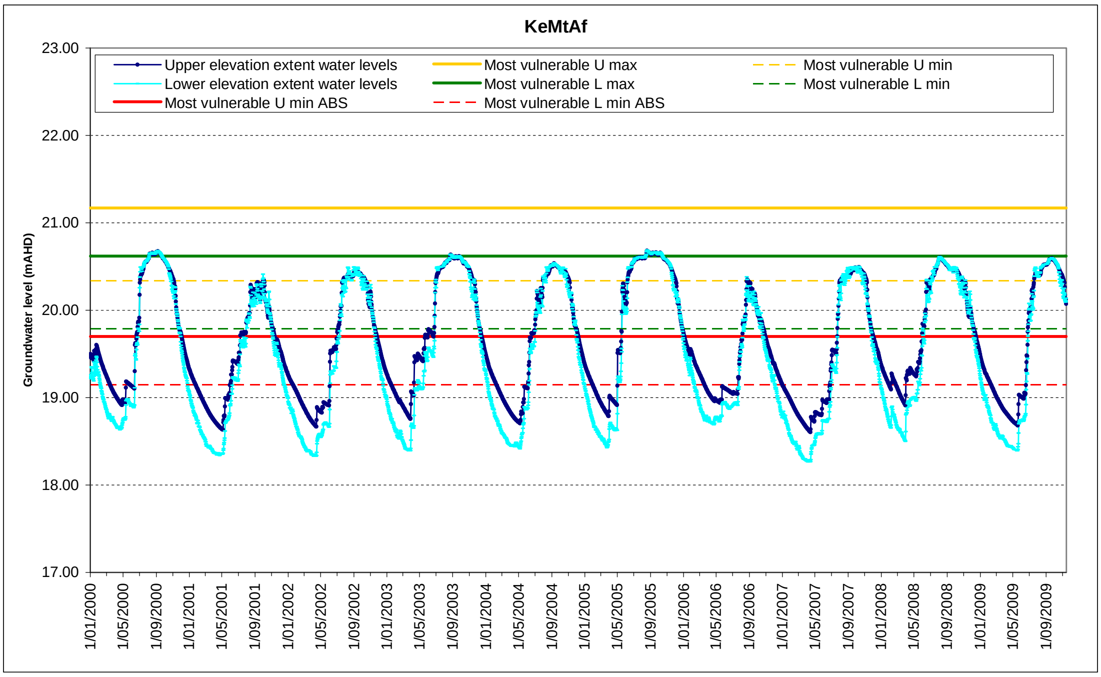
Vegetation community BmBi



Vegetation community MpMr

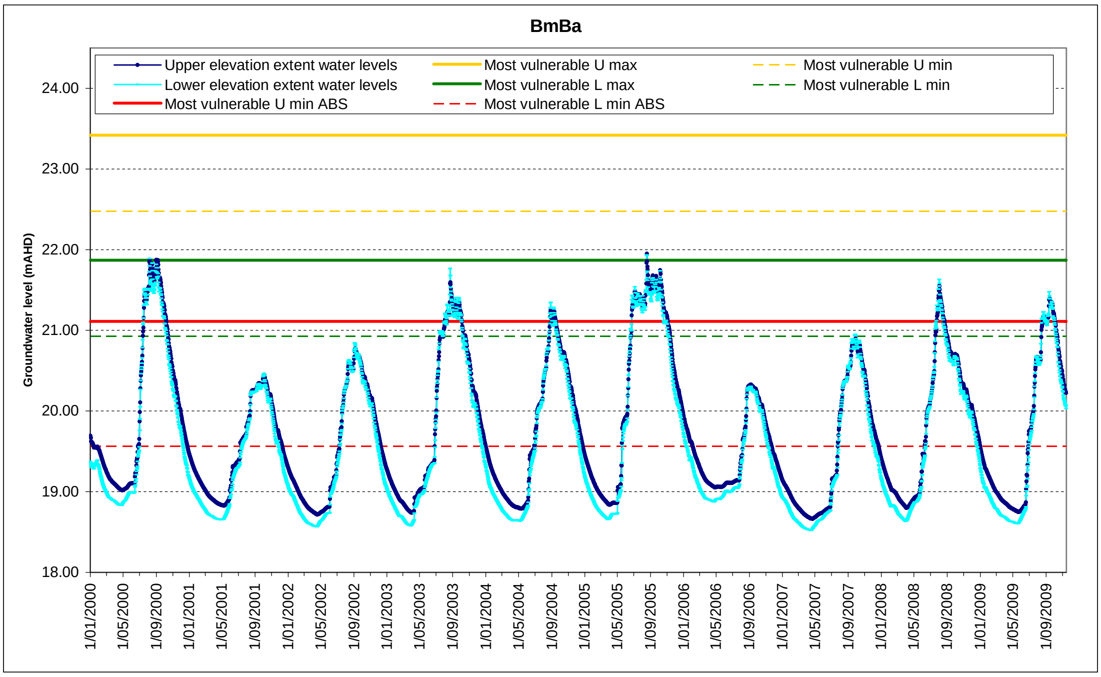


Vegetation community KeMtAf

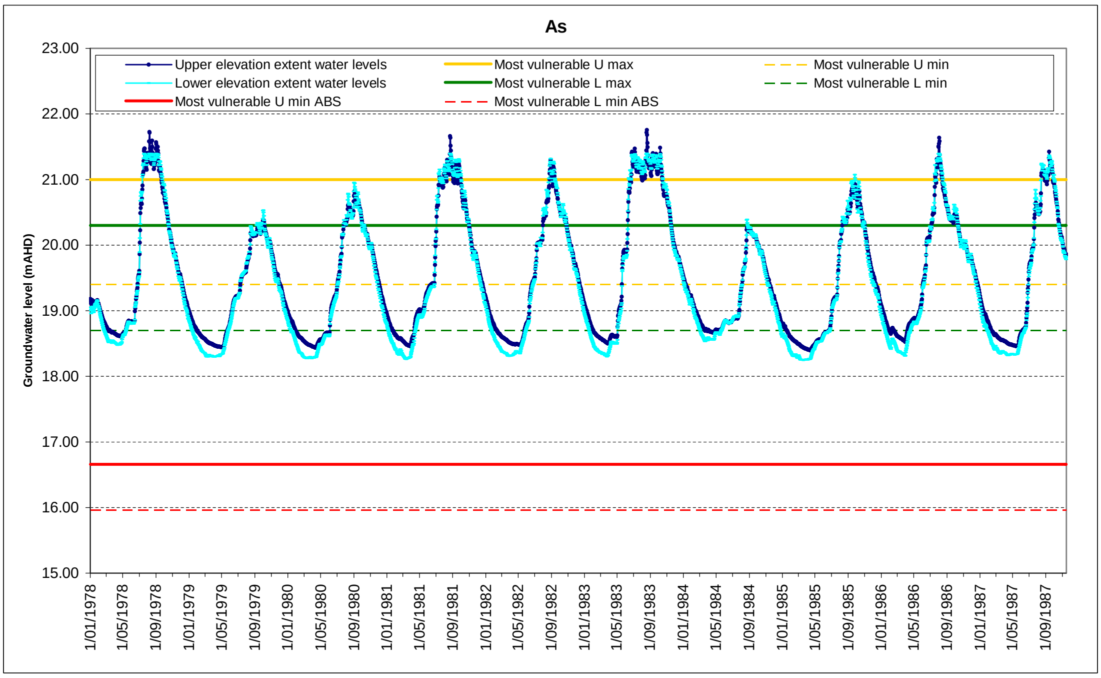


Elliott Road South wetland

Vegetation community BmBa

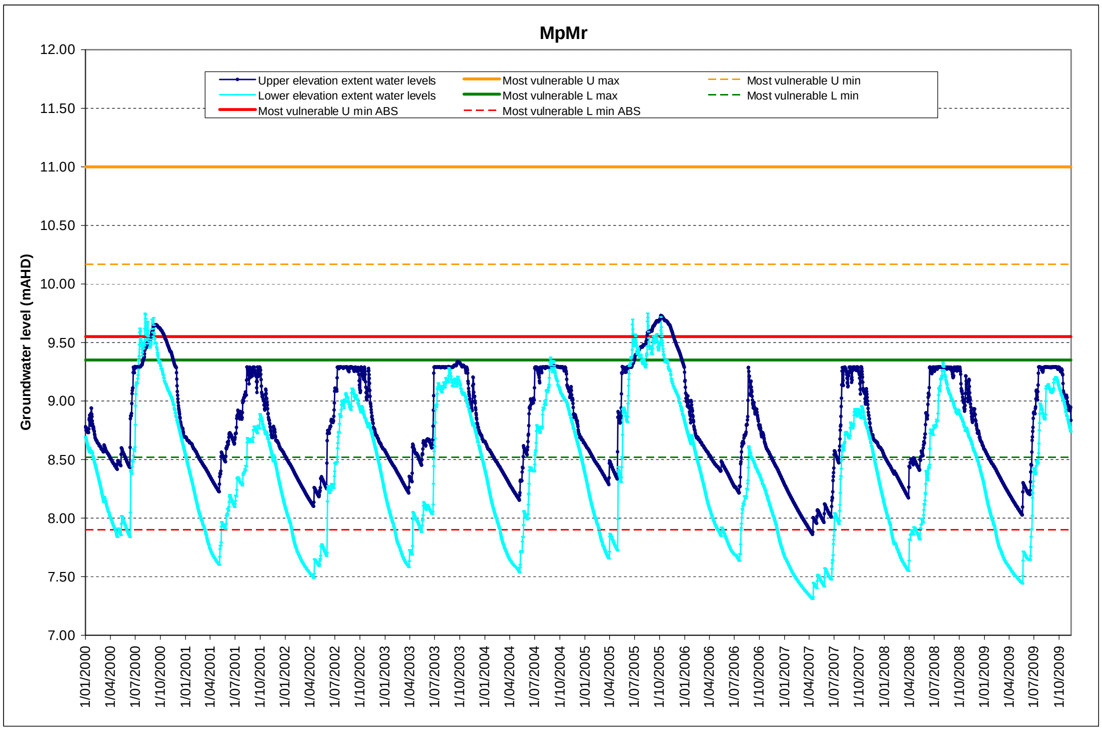


Vegetation community As

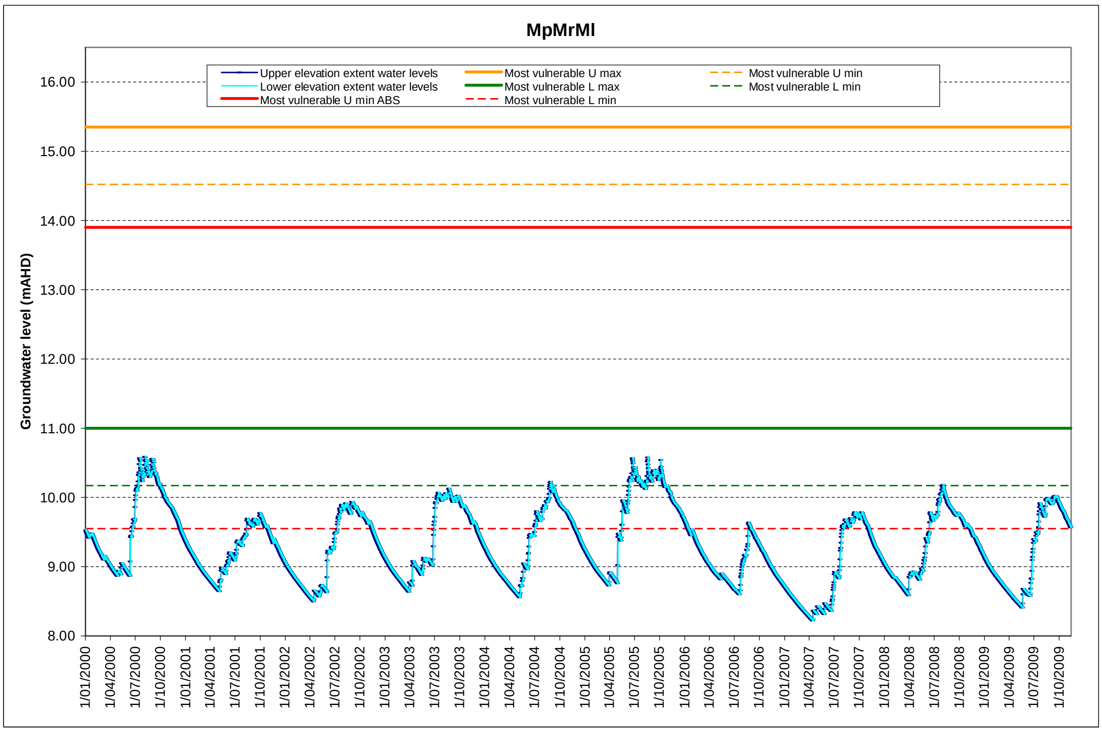


Airfield North wetland

Vegetation community MpMr

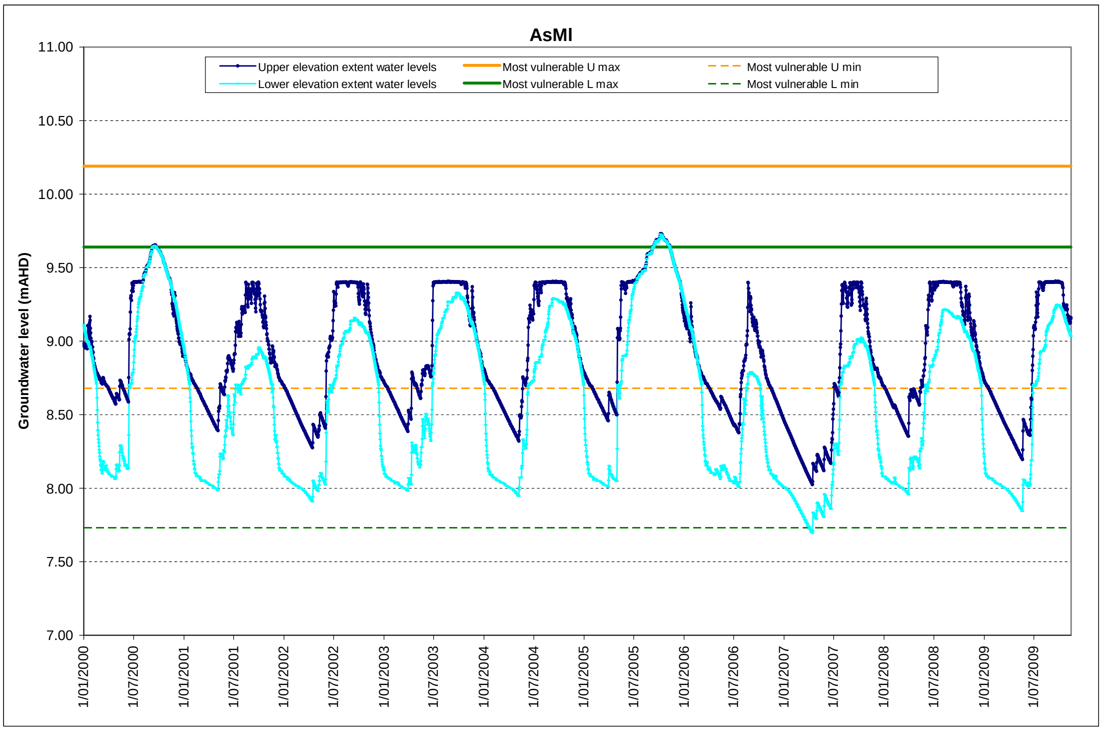


Vegetation community MpMrMl

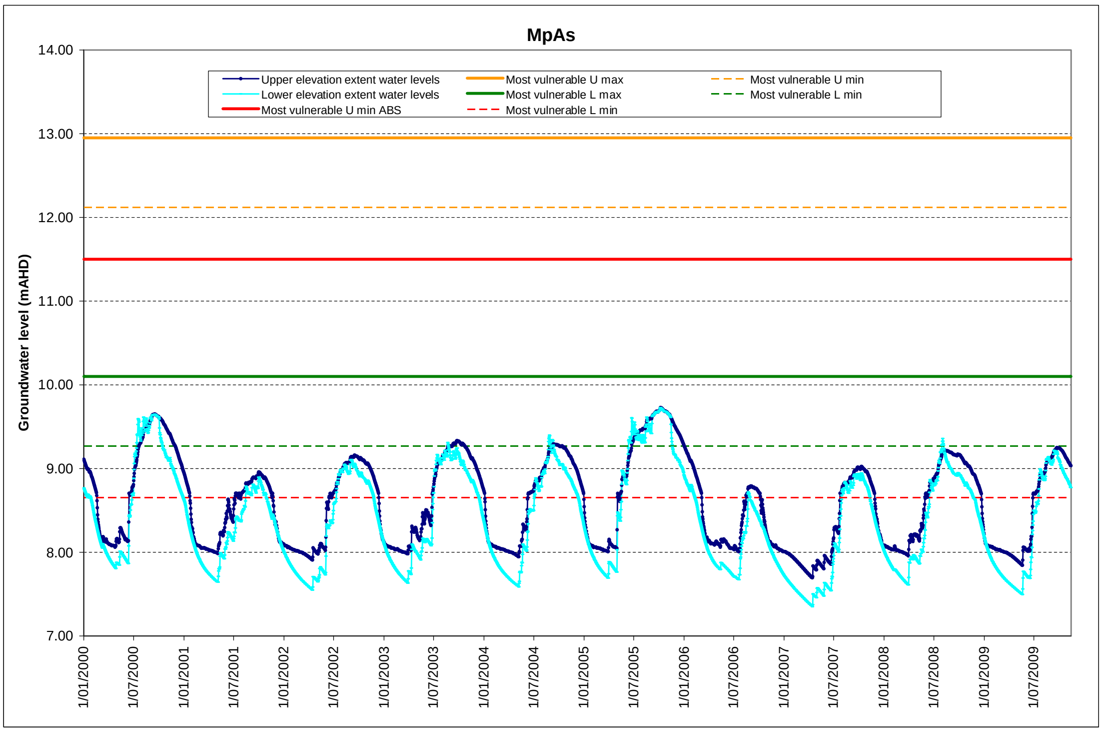


Airfield South wetland

Vegetation community AsMl

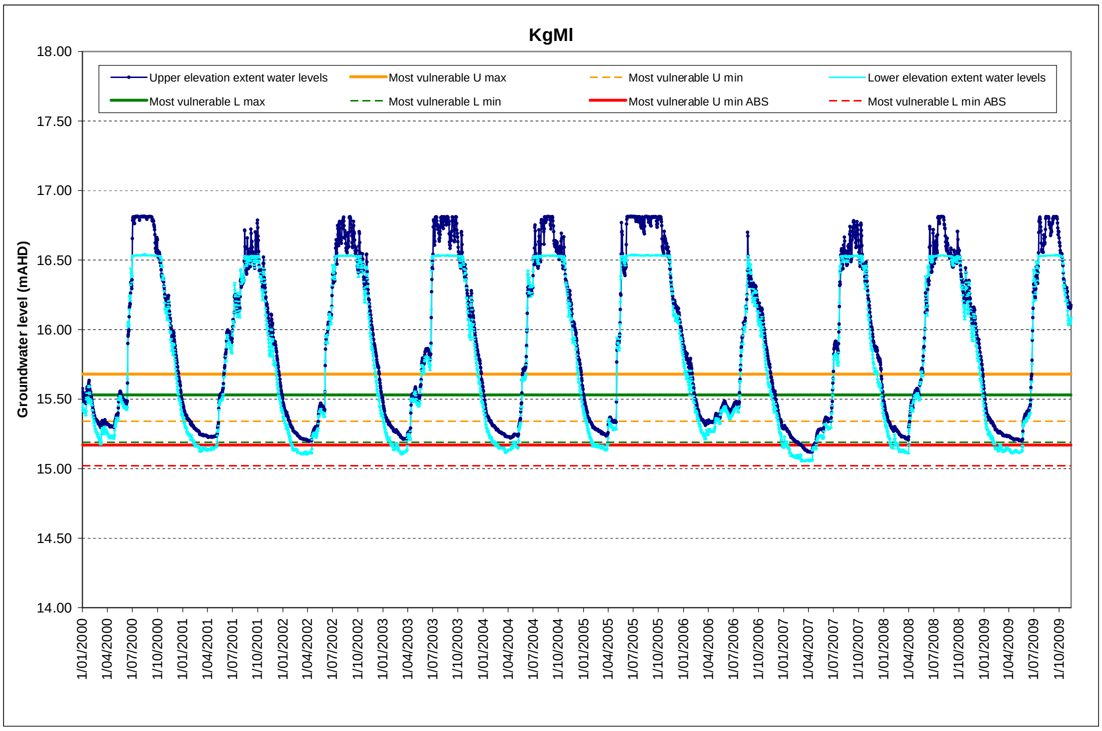


Vegetation community MpAs



Greyhound Road wetland

Vegetation community KgMl



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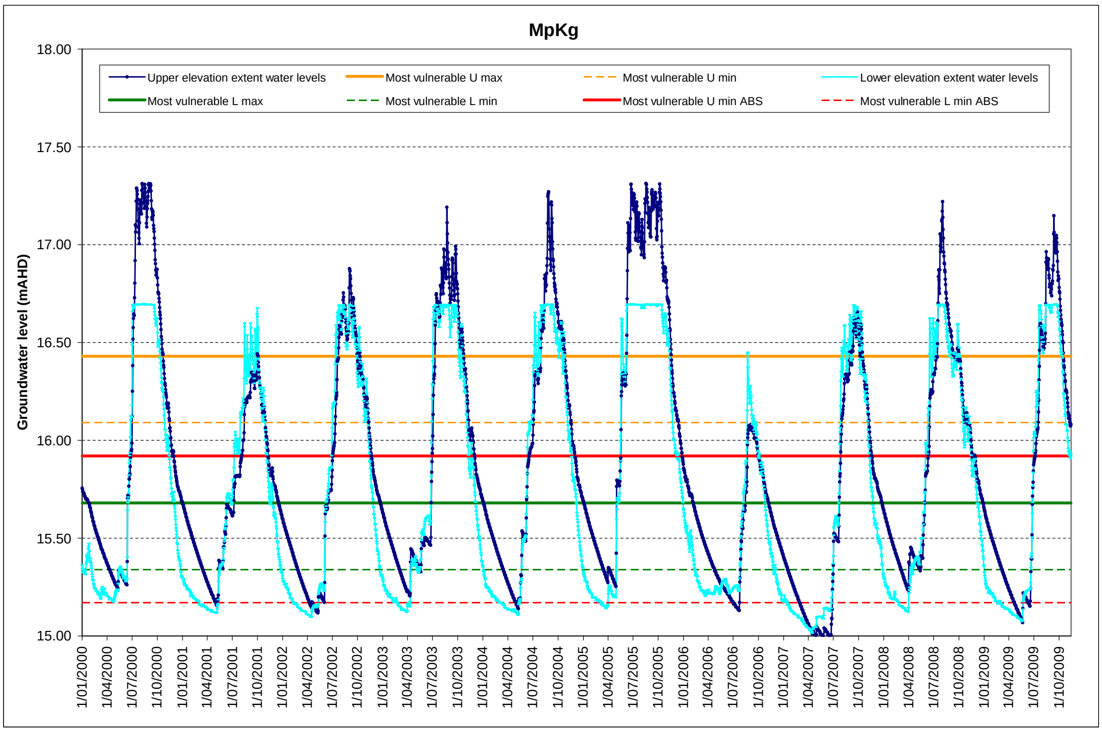
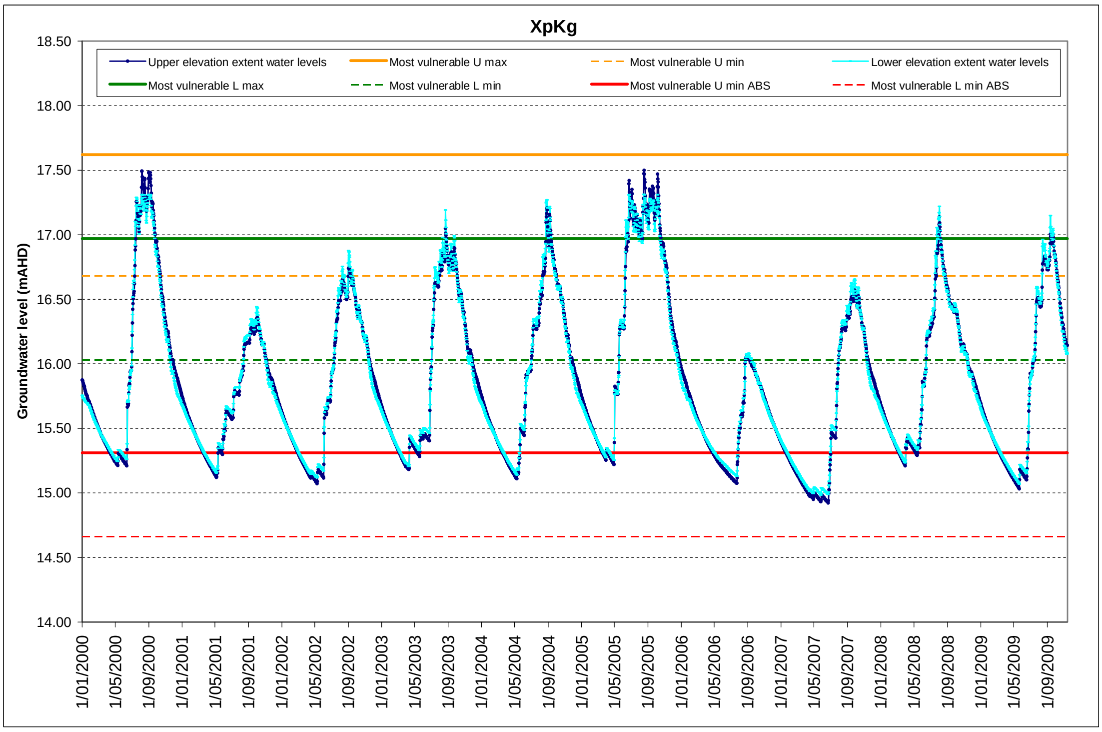
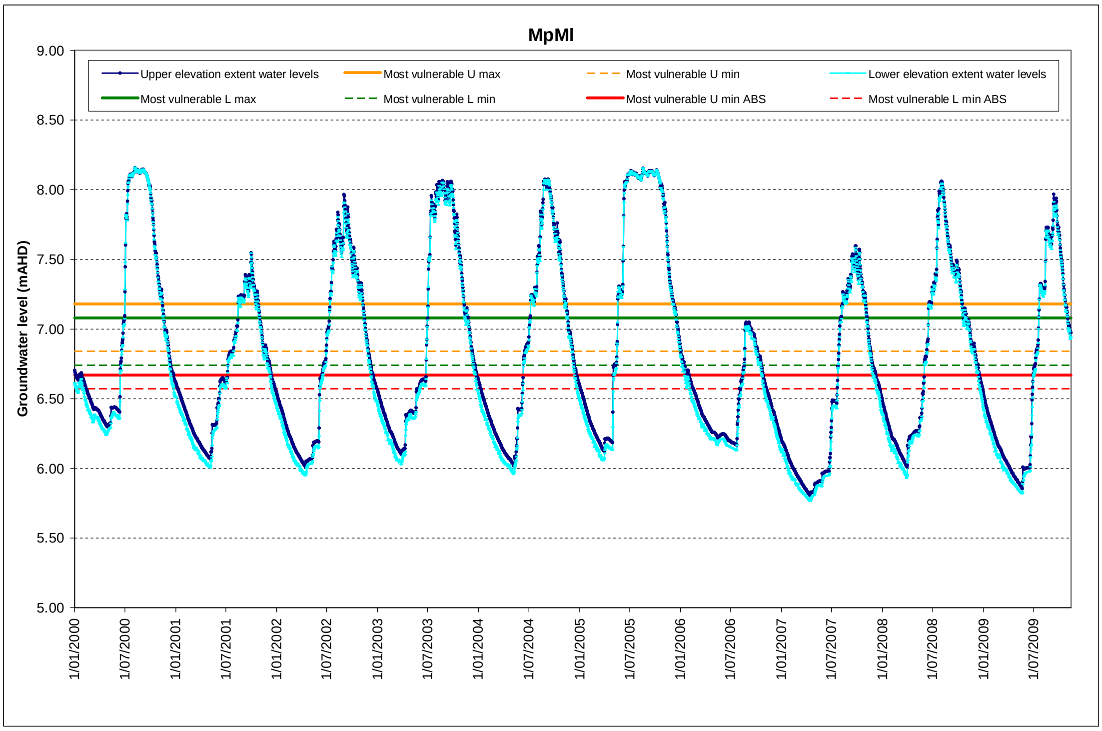


Vegetation community XpKg

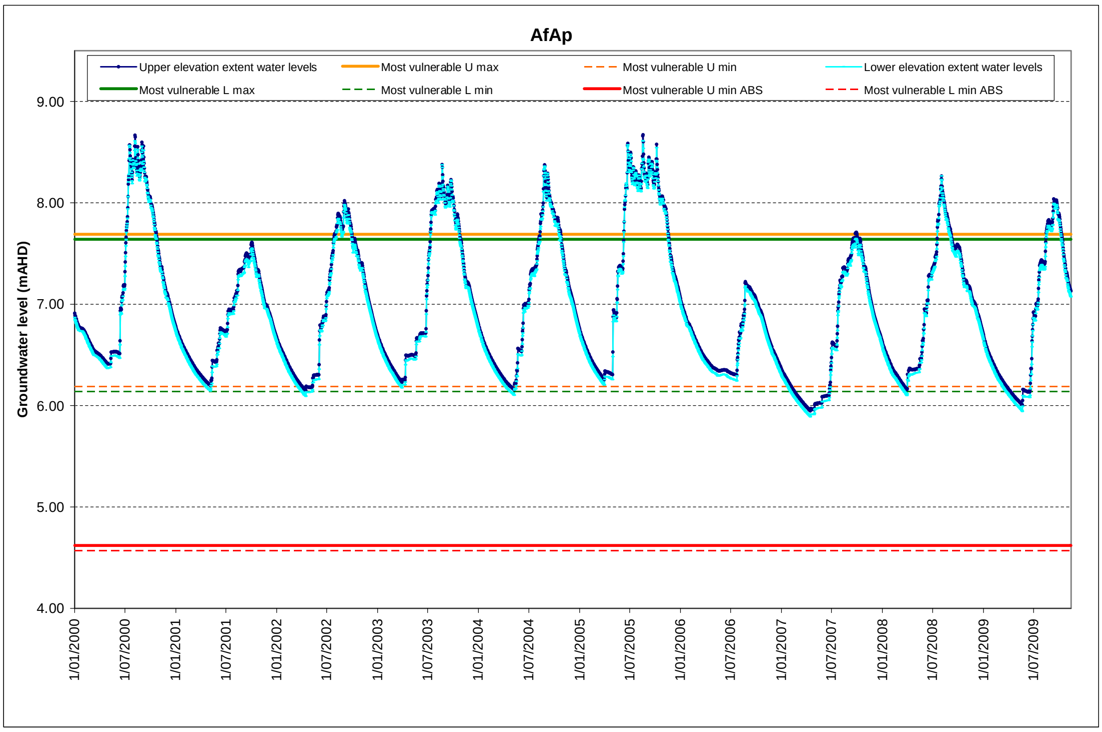


Phillips Road wetland

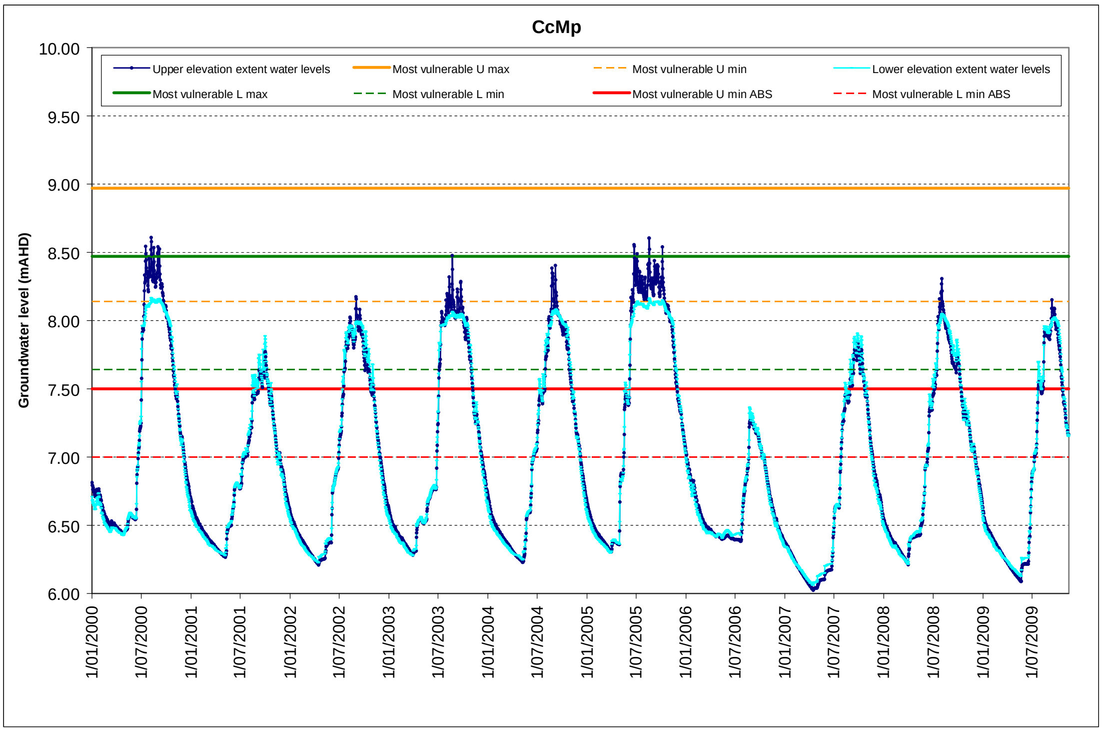
Vegetation community MpLl



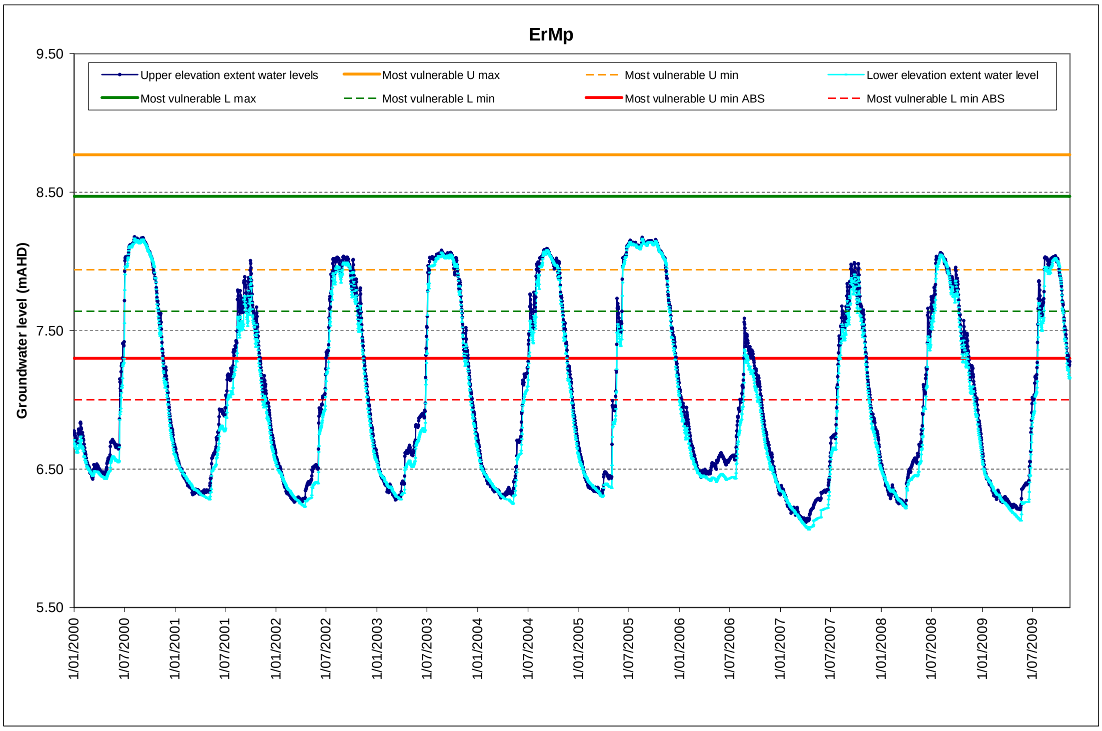
Vegetation community AfAp



Vegetation community CcMp



Vegetation community ErMp

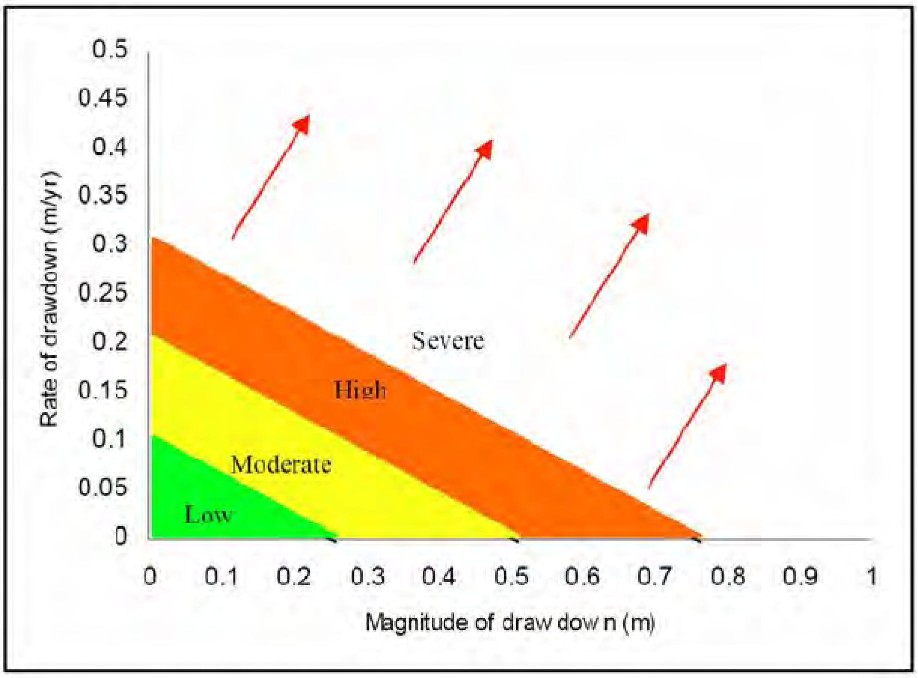


Appendix E

Risk of impact models

Froend *et al.* (2004)

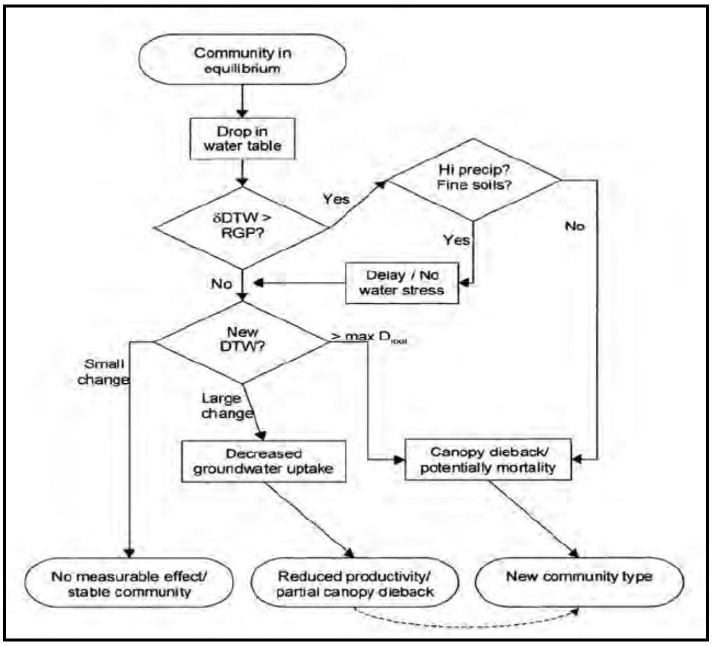
The figure below displays the conceptual model of risk of impacts to wetland vegetation developed by Froend *et al.* (2004).



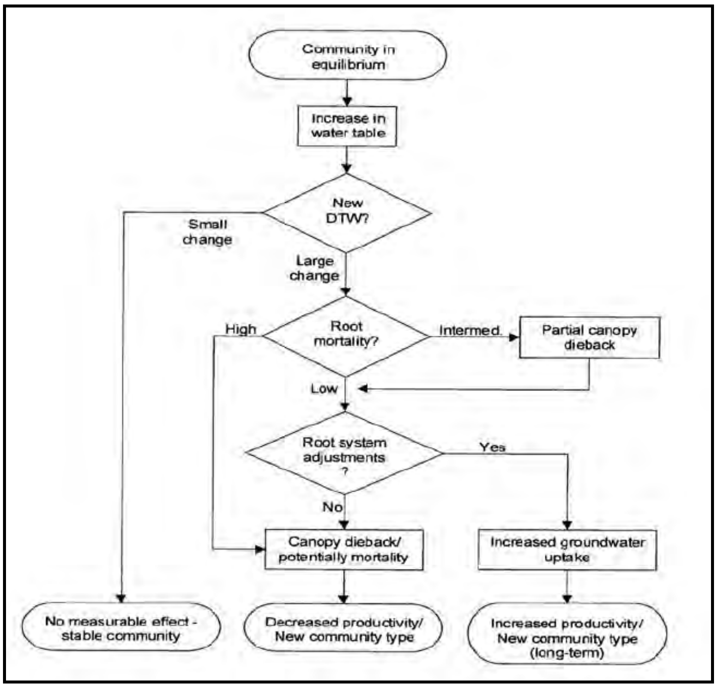
Naumburg *et al*. (2005)

Naumburg *et al.* (2005) developed two conceptual models describing the predicted changes to phreatophytic vegetation based on an increase or decline in water levels.

Decrease in water level



Increase in water level



GHD

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